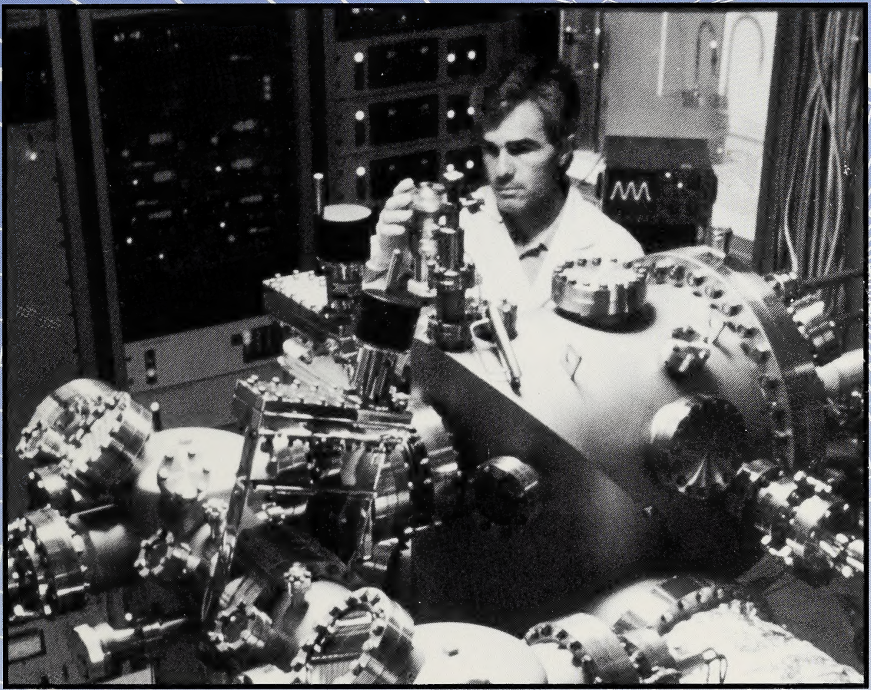
PHYSICS 30



Modules 1-9

Learning Facilitator's Manual

Distance Learning

Alberta
EDUCATION

Physics 30

LEARNING FACILITATOR'S MANUAL

Distance Learning

Alberta EDUCATION

NOTE: This Physics 30 Learning Facilitator's Manual contains answers to teacher-assessed assignments and the final test; therefore, it should be kept secure by the teacher. Students should not have access to these assignments or the final test until they are assigned in a supervised situation. The answers should be stored securely by the teacher at all times.

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This document is intended for	
Students	
Teachers (Physics 30)	✓
Administrators	
Parents	
General Public	
Other	

Physics 30
Learning Facilitator's Manual
Modules 1-9
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Teachers

Register with the Alberta Distance Learning Centre

The Alberta Distance Learning Centre is dedicated to upgrading and continually improving your Learning Facilitator's Manual so that it accurately reflects any necessary revisions we have had to make in the student module booklets, assignment booklets, or the sample final test. The types of revisions that will be made are those that make the course more accurate, current, or more effective.

The ADLC will send you the **latest enhancements or minor upgrades** for your Learning Facilitator's Manual if you return the following registration card to: Alberta Distance Learning Centre, Box 4000, Barrhead, Alberta, T0G 2P0, Attention: Instructional Design and Development.

ADLC Learning Facilitator's Manual
Registration Card

First Name	Surname
School Name	School Phone Number
School Address	
City	Postal Code
Course Title	Approximate Date of Purchase

You can help ensure that distance learning courseware is of top quality by letting us know of areas that need to be adjusted. Call the Alberta Distance Learning Centre free of charge by using the RITE line and ask for the Editing Unit. Also, a teacher questionnaire has been included at the back of most Learning Facilitator's Manuals. Please take a moment to fill this out.

We look forward to hearing from you!

Contents

Introduction

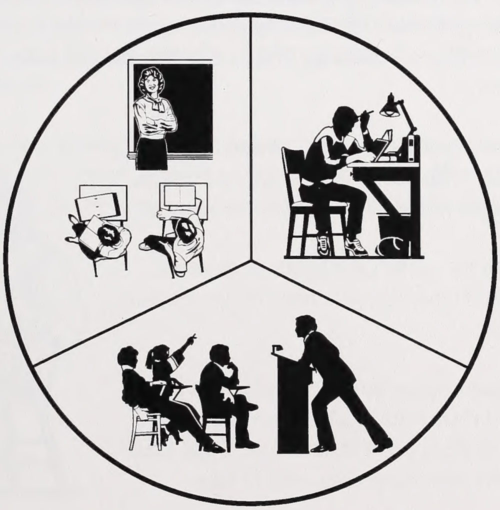
A survey of these course materials will confirm that this new learning package has been specially designed for many kinds of teachers working in a variety of situations.

Which Category Do You Fit?

- ❑ Small Schools Teacher
  - ❑ inexperienced
  - ❑ experienced, but in other subject areas
  - ❑ experienced in teaching Physics 30, but wanting to try a different approach

- ❑ Distance Learning Teacher
  - ❑ travelling to schools within the jurisdiction
  - ❑ using facsimile and teleconferences to teach students within the area

- ❑ Larger Schools Teacher
  - ❑ inexperienced
  - ❑ experienced in teaching Physics 30, but wanting to try a different approach



Because these materials have been created by experienced classroom teachers and distance learning specialists, they have many advantages for students and teachers regardless of their situations.

Advantages for Students

- incorporates a strong learner-centred philosophy
- promotes such qualities in the learner as autonomy, independence, and flexibility
- is developed through media which suit the needs and circumstances of the learner
- reflects the experiential background of Alberta students
- opens up opportunities by overcoming barriers that result from geographical location
- promotes individualized learning, allowing learners to work at their own pace

Advantages for Teachers

- allows teachers maximum teaching time and minimizes preparation time
- includes different routes through the materials to suit different learners
- incorporates a wide range of teaching strategies, in particular those using independent and individual learning
- delivers curriculum designed by education specialists that reflects the Alberta Education Program of Studies with an emphasis on Canadian content
- provides learning materials which are upwardly compatible with advanced educational technology

Does it sound like something you could use?

This Learning Facilitator's Manual begins with an overview of the current Alberta Education Program of Studies for Physics 30. This summary is included for inexperienced teachers or those teachers who have found themselves teaching Physics 30 when their training is in other subject areas. This brief summary is not meant to replace the Alberta Education Program of Studies, but rather to help teachers confirm the highlights of the program.

Other parts of this introduction have also been included to help teachers become familiar with this new learning package and determine how they might want to use it in their classroom.

Beyond the introduction the guide itself contains answers, models, explanations, and other tips generated by the teachers who authored this course.

The module booklets, assignment booklets, and LFMs are the products of experienced classroom teachers and distance learning specialists. It is the hope of these teachers that their experience can be shared with those who want to take advantage of it.

Overview of the Program of Studies

The *Physics 20-30 Program of Studies* will be an important document for you as a teacher of Physics 30. Once you understand the rationale behind the course and the expectations of students, you'll know how the different components work together, and you'll be able to make better decisions when planning. Starting with the program of studies is a good investment in time. So, before proceeding any further, you should get the most recent version of this document and the Module 1 Student Module Booklet.

To help make the best use of your time, you'll be asked to read exerpt pages from the *Program of Studies* and then key ideas will be highlighted with supporting examples from the Student Module Booklet. To begin, please read Program Rationale and Philosophy, found near the beginning of the *Program of Studies*.

Did you notice the emphasis on students learning the big, interconnecting ideas in a relevant context? This philosophy translates into strategies such as providing the Physics 30 data sheets for students during exams since the focus is not on memorizing equations, but on applying main ideas. Another example can be found in the first activity at the beginning of Module 1. Please skim this activity and note the focus on main ideas being put into a relevant context.

Please read General Learner Expectations, which is found near the beginning of the *Program of Studies*. Pay particularly close attention to the section on skills. It could be argued that the skills may be of greater value to the life-long learning of the student than to the specific course content. Clearly, these skills are intended to be a central part of the course. The Student Module Booklet has attempted to make these skills explicit to the students as they progress through the course. Carefully read through the third and fourth activities in Module 1 and the science skills section, which is found at the beginning of the Appendix of Module 1.

How should Physics 30 be taught? Although there are a variety of answers to this question, the learning cycle is an approach that many successful science teachers have used for years. Please read Specific Learner Expectations, found near the beginning of the *Program of Studies,* to learn more about the learning cycle. Examples of how the learning cycle can be applied to student learning can be found in each section of the Student Module Booklet. Please quickly survey these pages to find evidence of the learning cycle being used.

Having worked from very general statements about philosophy to the specifics of the learning cycle, it is appropriate to wonder what topics actually comprise the Physics 30 course. The following chart shows how the units outlined in the *Program of Studies* relate to the student modules produced by the Alberta Distance Learning Centre.

Physics 30 Program of Studies		ADLC Physics 30		Recommended Percentage of Available Instructional Time
Unit	**Title**	**Module**	**Title**	
1	Conservation Laws	1	The Conservation of Energy	13%
		2	The Conservation of Momentum	12%
2	Electric Forces and Fields	3	Static Electricity	12%
		4	Current Electricity	13%
3	Magnetic Forces and Fields	5	Magnetism	12%
		6	Electromagnetism	13%
4	The Nature of Matter	7	Quantum Theory	9%
		8	Physics for Life: Assessing Risks and Benefits	5%
		9	Models of the Atom	11%

These topics provide ample opportunity for you to make connections between science, technology, and society. This is known as the STS approach to science education. If you remember what you learned about the learning cycle (from the section called Specific Learner Expectations in the *Program of Studies*), the STS approach means more then adding extra societal or technological lessons to the end of each unit. The STS approach means that a relevant STS context will likely begin the presentation of each topic and then weave its way through to the end of the unit. As an instructor, the idea is not to think of the STS topics as extra content to teach, but rather as a motivational theme throughout the unit.

As an example, turn to Activity 1 of Section 2 in the Module 1 Student Module Booklet. Read this activity to look for examples of the physics being put in a relevant context for the students. Can you think of other examples that would help to make this more meaningful to the students? Is there an application unique to the lives of your students that could enrich this presentation further? There's always room for your own improvements and innovations, but you'll problably agree that the presentation style in this first activity is much better than giving the students all the definitions at once and then asking them to apply them later.

When you plan your teaching, you should begin by identifying the STS themes that are relevant to you and your students. Although the *Program of Studies* has the STS connections column on the far right side when describing the specific concepts, that does not mean that they should happen last. In the distance learning materials, these STS connections are made for the students at the beginning of each section.

Teaching Strategies

The important thing for an instructor to bear in mind when planning to teach the Physics 30 course is that this program requires a disciplined approach to the subject matter on the part of the student. **How** the students manipulate data, solve problems, and communicate solutions is just as important, if not more so, as **what** topic they happen to be studying. It is vital that you as an instructor be very consistent in how you do things. Students will need to be continually encouraged to think about the big, interconnecting ideas, while at the same time correctly managing all the little details. This foresight that students require is the theme of Section 1 of Module 1. You should read through this section and the corresponding Appendix answers before you begin to teach the course, as this will help you get a sense of the disciplined approach required by students.

The disciplined approach that is recommended is designed to help students to be successful. There are four key areas of development in which students are expected to grow and develop as they work through the program. These areas are as follows:

- the ability to correctly use vector notation and vector analysis to solve a wide variety of problems
- the ability to apply the conservation laws, particularly the law of conservation of energy, to solve a wide variety of problems
- the ability to link concepts from different parts of the Physics 20/30 Program to solve non-routine, unique problems
- the ability to apply graphical analysis techniques (curve straightening and slope/intercept interpretations) to sample data collected from representative experiments. These experiments could relate to any major concept from the course.

These four areas have been integrated wherever possible into each of the modules of the course. If you skim through the Module 1 Student Module Booklet, you can find plenty of illustrations of the last three of these areas. (Since energy is a scalar topic, vectors do not come to the forefront until Module 2.)

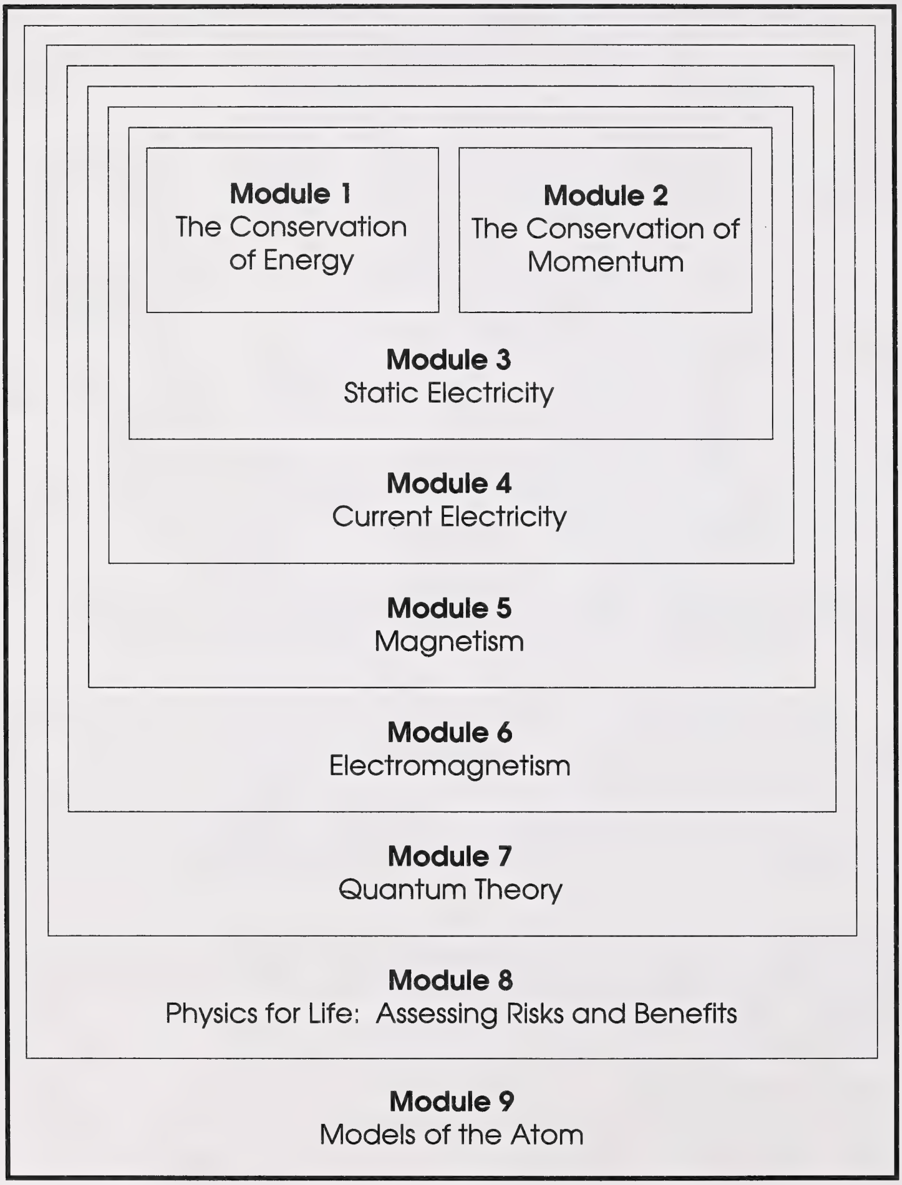
It's worth considering the role of the textbook in all of this. The textbook is a motivating text with a good readability level and a good selection of routine, introductory problems. The text does not really address the four areas previously mentioned. This means that you will have to guard against the tendency to teach the textbook. Instead your goal should be to successfully guide students through the program of studies. The distance learning materials have been designed with this in mind, so, when in doubt, the distance learning materials are a better indicator of what students are expected to learn.

The last comment to make concerns the Physics 30 Diploma Exam. The distance learning materials have been written to prepare students to be successful on this exam. However, the exam changes over time and eventually may go in some new directions that were not anticipated when the distance learning materials were developed and printed. It is important for you to have a clear sense of any new initiatives being introduced on the exam. The best way to keep on top of this is to collect and study the exam bulletins that are mailed to school jurisdictions from Student Evaluation Branch. It's also a good idea to volunteer for item writing committees and diploma exam marking sessions. These experiences will keep you in touch with the latest developments in student evaluation and they are also an excellent professional development activity.

Overview of Physics 30

This course contains nine modules. The first two modules develop the conservation laws of energy and momentum. The conservation of energy is at the heart of the entire course. Modules 3 through 9 build one upon the other and incorporate the main ideas from the preceding modules.

PHYSICS 30

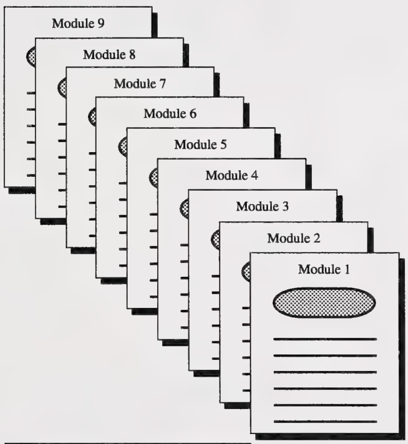


Structure of the Learning Package

Basic Design

This new learning package involves many other components in addition to the Learning Facilitator's Manual.

Modules



Contents
Overview Evaluation
Section 1 Activity 1 Activity 2 etc.
Section 2 Activity 1 Activity 2 etc.
Section 3 Activity 1 Activity 2 etc.
Section 4 Activity 1 Activity 2 etc.
Module Summary

The print components involve many booklets called modules. These modules contain guided activities that instruct students in a relevant, realistic setting.

The modules have been specially designed to promote such qualities in the learner as autonomy, independence, and flexibility. Writers have incorporated such teaching strategies as working from the concrete to the abstract, linking the old to the new, getting students actively involved, and using advance, intermediate, and post organizers. Many other techniques enable learners to learn on their own for at least some of the time.

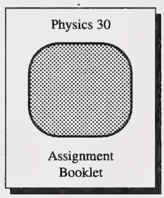
The structure of the module booklets follows a systematic design. Each module begins with a detailed table of contents which shows the students all the main steps. It acts as an organizer for students. The overview introduces the module topic or theme. A graphic representation has been included to help visual learners and poor readers. The introduction also states the weightings of each assignment.

The body of the module is made up of two or more closely related sections. Each section contains student activities that develop skills and knowledge centred around a theme.

The activities may involve print, audio, video, computer, or laser videodisc formats. At times the student and the learning facilitator are allowed to choose the activity that best suits the student's needs and interests. Other activities such as the Extra Help and Enrichment are optional pathways. This flexibility caters to each student's personal situation.

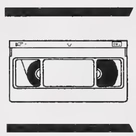
The summary focuses on the skills and strategies that the student has learned.

Assignment Booklet

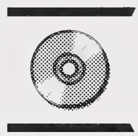


Accompanying each module is an assignment booklet. The activities in these booklets can be used for formative and for summative assessments. The students should complete these assignment booklets when they have thoroughly reviewed the module materials. The assignment booklets have been designed for classroom use, for faxing, or for mailing. **If the booklets are not being mailed, you should remove the outside cover.**

Media



VIDEOCASSETTE



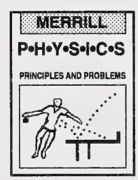
LASER
VIDEODISC

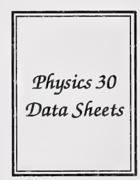
The package also includes references to media. Some types of media such as computer disks and laser videodiscs are optional choices for students; however, there are activities that require students to view certain videos. These mandatory videos are listed on the following page. It is important that you acquire these videos as you are planning the course. In addition to the mandatory videos, optional videos have been mentioned at various points in the modules. A list of the optional videos is also included on the following page. More information about the videos can be found within the LFM.

Textbooks and Reference Books

- The package requires students to use *Physics: Principles and Problems*, published by Maxwell Macmillan, as their textbook.

- The package also requires students to use the Physics 30 data sheets which can be found at the end of the appendix of Module 9.





Lab and Other Materials

The package includes references to lab materials. A list of necessary materials is included later in this manual.

Materials, Media, and Equipment

Mandatory Components

Equipment (Hardware)	Media	Materials
• VCR	• Mandatory Video List: *Electricity* *Electromagnetism* *Structure of the Atom* *Wave Particle Duality* *Nuclear Physics* All of the videos are 1 h long (six 10-min programs). These videos were originally produced by TV Ontario.	• LFM for Physics 30 • one complete set of module booklets (9) and assignment booklets (9) for each student • There is a final test.

Videocassettes or laser videodiscs used in the course may be available from the Learning Resources Distributing Centre or ACCESS Network. You may also wish to call your regional library service for more information.

Optional Components

Equipment (Hardware)	Media	Materials
• laser videodisc player	• videocassettes • laser videodiscs *Physics: Cinema Classics* – a set of three discs (Available from D.C. Heath Canada Ltd.) • Optional Video List: *Concepts in Mathematics – Vectors* This video is 1 h long (six 10-min programs). The first four programs are helpful as a review/tutorial prior to starting Module 2. This video was originally produced by TV Ontario.	

Using This Learning Package in the Classroom

Conventional Classroom

Whether your classroom has desks in rows or tables in small groups, you may be most comfortable with a learning system that you can use with all your students in a paced style. In other words, you may want a package that will suit all of your students, so they can move through the materials as one group or several small groups. Because these materials contain different routes or pathways within each module, they can address various learning styles and preferences. The materials also include many choices within the activities to cater to different thinking levels and ability levels. Because of their versatility and flexibility, these materials can easily suit a conventional classroom.

Open-Learning Classroom

Open learning is the concept of opening up opportunities by overcoming barriers of time, pace, and place by giving the learners a package specially designed to enable them to learn on their own for at least some of the time.

Such a concept is not new. Many teachers can recite attempts to establish an individualized learning system as they recognized the importance of trying to personalize courseware to meet each individual student's needs. But these efforts often failed due to lack of time and lack of quality materials that conformed to Alberta specifications.

Due to advanced educational technology and improved Alberta-specific learning packages, a student-centred approach is now possible. Improved technology now allows us to provide support to learners individually, regardless of their pace or location. A teacher cannot be in twenty-eight places at one time offering guidance. However, media and a well-designed learning package can satisfy individual needs. Technology can also help provide an effective management system needed to track the students as they progress independently through the materials.

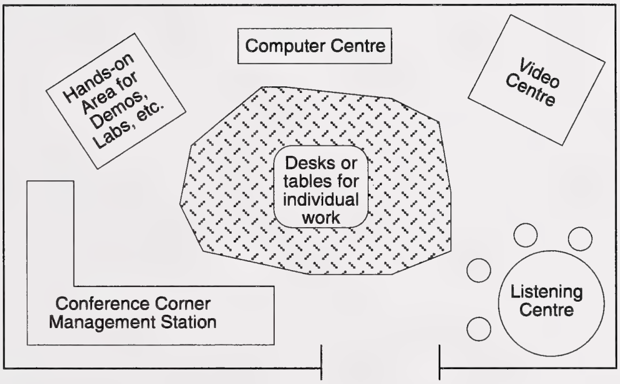
The key to a successful open-learning system depends on three vital elements: a learning package specially designed to enable students to learn effectively on their own for at least some of the time; various kinds of learner support; and a management system and style that ensures that the open-learning system runs smoothly.

The Key to a Successful Open-Learning System

Learning Package

The specially designed learning package needed for a successful open-learning system has been developed for you. The objectives teach current Alberta specifications using strategies designed for individualized instruction. As the learning facilitator, you need to be sure to have all the components in the learning package available to students as needed.

If adequate numbers of media are available to satisfy the demand, a centre can be established for specific media.



You may not have the luxury to have enough hardware to set up a permanent video or computer centre in your classroom. In that case, students should be encouraged to plan ahead. Perhaps every three to five days they should preview their materials and project when they would need a certain piece of media. This would allow you to group students, if necessary, or reserve media as required.

Support

Support is definitely a key element for successful learning, and when you're planning an individualized, non-paced program, you need to carefully plan when and how support will be given.

The materials contain a form of consistent support by providing immediate feedback for activities included in the module booklet. High school students have solutions, models, explanations, and guides included in the appendix of every module booklet. These are included so students can receive immediate feedback to clarify and reinforce their basic understanding before they move on to higher levels of thinking.

As the learning facilitator, you may be needed to offer more personal guidance to those students having difficulty, or you may need to reinforce the need for students to do these activities carefully before attempting the assignments in the assignment booklet.

The activities include choices and pathways. If a student is having difficulty, you may need to encourage that student to work on all the choices rather than one. This would provide additional instruction and practice in a variety of ways.

Another form of support is routine contact with each individual. This might be achieved with a biweekly conference scheduled by you, or as students reach a certain point (e.g., after each section is completed), they may be directed to come to the conference area.

Special counselling may be needed to help students through difficult stages. Praise and encouragement are important motivators, particularly for those students who are not used to working independently.

Direct teaching may be needed and scheduled at certain points in the program. This might involve small groups or a large group. It might be used to take advantage of something timely (e.g., election, eclipse, etc.), something prescheduled like the demonstration of a process, or something involving students in a hands-on, practical experience.

Support at a distance might include tutoring by phone, teleconferencing, faxing, or planned visits. These contacts are the lifeline between learners and distance education teachers, so a warm dialogue is essential.

Management

Good management of an open-learning system is essential to the success of the program. The following areas need action to ensure that the system runs smoothly:

- Scheduling, Distributing, and Managing Resources – As discussed earlier, this may require a need for centres or a system for students to project and reserve the necessary resources.
- Scheduling Students – Students and teachers should work together to establish goals, course completion timelines, and daily timelines. Although students may push to continue for long periods of time (e.g., all morning), teachers should discourage this. Concentration, retention, and motivation are improved by taking scheduled breaks.
- Monitoring Student Progress – You will need to record when modules are completed by each student. Your data might also include the projected date of completion if you are using a student contract approach.

Sample of a Student Progress Chart

Physics 30		Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8	Module 9	Final Test
Billy Adams	P										
	A										
Louise Despins	P										
	A										
Violet Klaissian	P										
	A										
P = Projected Completion Date A = Actual Completion Date											

The student could keep a personal log as well. Such tracking of data could be stored easily on a computer.

- Recording Student Assessments – You will need to record the marks awarded to each student for work completed in each module assignment booklet. The marks from these assignment booklets will contribute to a portion of the student's final mark. Other criteria may also be added (a special project, effort, attitude, etc.). Whatever the criteria, they should be made clear to all students at the beginning.

Sample of a Student Assessment Chart

Physics 30	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8	Module 9	Year's Average	Final Test	Final Mark
Billy Adams	**67**	**65**	**54**	**47**	**78**	**67**				**63**		
Louise Despins	**43**	**50**	**54**	**55**	**48**	**42**				**49**		
Violet Klaissian	**65**	**65**	**66**	**68**	**67**	**70**				**67**		

Letter grading could easily be substituted.

- Recording Effectiveness of System – Keep ongoing records of how the system is working. This will help you in future planning.

Sample of a System Assessment Chart

Module 1			
Date	Module Booklet	Assignment Booklet	Resources/Media

The Role of the Teacher in an Open-Learning Classroom

The teachers in a conventional classroom spend a lot of time talking to large groups of learners. The situation in open learning requires a different emphasis. Teachers will probably meet learners individually or in very small groups.

With this approach it is necessary to move beyond the idea of a passive learner depending largely on a continually supportive teacher. The teacher must aim to build the student's confidence, to stimulate the learner into self-reliance, and to guide the learner to take advantage of routes that are most meaningful and applicable to the learner.

These materials are student-centred, not teacher-centred. The teacher needs to facilitate learning by providing general support to the learner.

Evaluation

Evaluation is important to the development of every learner. Data gathering and processing, and decision making, at the student and teacher level, serve as means of identifying strengths and weaknesses.

These specially designed learning packages contain many kinds of informal and formal evaluation.

Observation

In the classroom the teacher has the opportunity to see each student perform every day and to become aware of the level and nature of each student's performance.

Observations are more useful if they are recorded in an organized system. The following list of questions is a sample of types of observations and how they can be collected.

Observation Checklist

	B. Adams	L. Despins	V. Klaissian	H. Smith	K. Dalley
1. Does the student approach the work in a positive manner?					
2. Is the student struggling with the reading level?					
3. Does the student make good use of time?					
4. Does the student apply an appropriate study method?					
5. Can the student use references effectively, etc.?					

Observation may suggest a need for an individual interview with a student.

Individual Conferences

Individual conferences may be paced (scheduled) by the calendar, at certain points in the module, or they may be set up only as needed or requested.

During these conferences teachers can determine the student's progress and can assess the student's attitudes toward the subject, the program, school, and self, as well as the student's relationship with other students. With guided questions the teacher can encourage oral self-assessment; the student can discuss personal strengths or weaknesses in regard to the particular section, module, or subject area.

Self-Appraisal

Self-appraisal helps students recognize their own strengths and weaknesses. Through activities that require self-assessment, students also gain immediate feedback and clarification at early stages in the learning process. Teachers need to promote a responsible attitude toward these self-assessment activities. Becoming effective self-assessors is a crucial part of becoming autonomous learners. By instructing, motivating, providing positive reinforcement, and systematically supervising, the learning facilitator will help students develop a positive attitude toward their own progress.

For variation, students may be paired and peer-assessing may become part of the system. The teacher may decide to have the student self-assess some of the activities, have a peer assess other activities, and become directly involved in assessing the remainder of the activities.

When the activities have been assessed, the student should be directed to make corrections. This should be made clear to students right from the start. It is important to note the correct association between the question and the response to clarify understanding, aid retention, and be of use for study purposes.

Many of the activities include choices for the student. If the student is having difficulty, more practice may be warranted, and the student may need to be encouraged to do more of the choices.

Each section within a module includes additional types of activities called Extra Help and Enrichment. Students are expected to be involved in the decision as to which pathway best suits their needs. They may decide to do both.

Self-appraisal techniques can also be introduced at the individual conferences. Such questions as the following might be included:

- What steps are you taking to improve your understanding of this topic?
- What method of study do you use most?
- How do you organize your material to remember it?
- What steps do you follow when doing an assignment?
- What could you do to become an even better reader?
- Do you have trouble following directions?
- Did you enjoy this module?

A chart or checklist could be used for recording responses.

Informal Evaluation: Assignments

Informal evaluation, such as the assignments included in each module, are an invaluable aid to the teacher. They offer ongoing assessment information about the student's achievement and the behaviour and attitudes that affect that achievement.

Each module contains a separate booklet called the Assignment Booklet. This booklet assesses the knowledge or skills that the student has gained from the module. **The student's mark for the module may be based solely on the outcome of learning evident in the assignment booklet; however, you may decide to establish a value for other variables such as attitude or effort.** It is important that you establish at the beginning which outcomes will be evaluated, and that all students clearly understand what is expected.

Final Test

All LFMs include a formal final test which can be photocopied for each member of the class. The test, closely linked to the learning outcomes stated in the module booklets, gives the teacher precise information concerning what each student can or cannot do. Answers, explanations, and marking guides are also included. The value of the final test and each module is the decision of the classroom teacher. Following is a suggestion only.

Module 1 6%	**Module 2** 6%	**Module 3** 6%	
Module 4 6%	**Module 5** 6%	**Module 6** 6%	**Final Test** 50%
Module 7 5%	**Module 8** 3%	**Module 9** 6%	

Introducing Students to the System

Your initiation to these learning materials began with a basic survey of what was included and how the components varied. This same process should be used with the class. After the materials have been explored, a discussion might include the advantages and the disadvantages of learning independently or in small groups. The roles of the students and teacher should be analysed. The necessary progress checks and rules need to be addressed. Your introduction should motivate students and build a responsible attitude toward learning autonomously.

Skill Level

It is important for students to understand that there are certain skills that they will need in order to deal successfully with the course materials. They are listed below:

- understanding and using instructional materials (table of contents, index, list of illustrations, appendices, bibliography, and glossary)

- interpreting maps, graphs, and charts

- using reference materials

- recognizing special symbols

- using a scientific calculator

Other general skills are using reliable study methods, outlining, and learning to read at a flexible rate.

To decide the level and amount of instruction needed to accommodate the varied levels among students, you may wish to prepare and administer skill inventories or pretests. If most students need help with a particular skill, you may want to plan a total class instructional session. If only certain students lack a skill, you may want to set up a temporary skill group to help students who need it, or you may want to develop a skills file for this purpose.

Reading Level

These course materials are largely print based, but poorer readers need not be discouraged. It is important that you assure the students that these materials have been designed for easy reading. The authors have employed special strategies that lower and control the reading level. Some of them are

- the conscious selection of vocabulary and careful structuring of sentences to keep the materials at an independent reading level

- the integration of activities, examples, and illustrations to break text into appropriate-sized chunks

- the inclusion of many kinds of organizers (advance, graphic, intermediate, concept mapping, post organizers) to help give students a structure for incorporating new concepts

- the recognition that vocabulary and concepts are basic to understanding content materials and, thus, must be handled systematically (defined in context, marginal notes, footnotes, and often in a specialized glossary)

- the acknowledgement that background knowledge and experience play a vital role in comprehension

- the systematic inclusion of illustrations and videos to help poorer readers and visual learners, and audiocassettes and software as an alternative to print-based learning

- a variety of formats (paragraphs, lists, charts, etc.) to help poorer readers who do not absorb or retain main ideas easily in paragraph format

- the inclusion of media and activity choices to encourage an active rather than passive approach

- instruction in a meaningful setting rather than in a contrived, workbook style

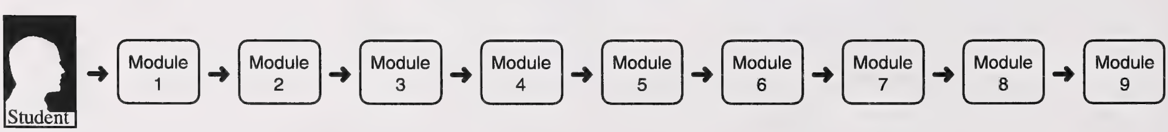
- using purposeful reading, viewing, and doing to produce better interpretation of the course materials

- the recognition that students need structured experiences when reading, viewing, or listening to instructional materials: developing pupil readiness, determining the purpose, providing guided instruction and feedback, rereading if necessary, and extending (This structure closely resembles the reading process.)

To help make the learning package more readable, you can begin your module preparation by reading (viewing, listening to) all the related materials that are going to be used. You need a solid background in order to assess and develop a background knowledge for students. The students' experiential bases may be assessed through brainstorming sessions concerning the topic, or by using visuals and guided questions to predict what the topic might be about.

It is recommended that you start with Module 1 because this module includes basic introductory information, and it is also recommended that you end with Module 9 because this module acts as a summary or culmination.

It is very important to note that Physics 30 is a course that depends upon laying a solid foundation with the beginning modules. It would be a mistake to rush students through any of the first five modules – especially Module 1. The last four modules are heavily dependent upon the foundation laid in the first five, so if a thorough job is done on the first five, you may be able to make up time and avoid reteaching when you come to the last part of the course. It is recommended that you do the modules in order from Module 1 to Module 9.



Suggested Answers

Module 1: The Conservation of Energy

Overview

This module gets a physics student off to a good start by first demonstrating the kind of approach needed for success in Physics 30. An introduction to graphical analysis techniques, problem-solving strategies, and science skills is done in the context of a review on energy. The second section develops the law of conservation of energy through a series of lab investigations and a variety of problems.

Module 1
The Conservation of Energy

Section 1
Starting with Energy and Foresight

Section 2
Exploring Energy Systems

The problem-solving approach developed in the last activity of Section 2 will become a cornerstone of much of the remaining work in Physics 30. It is important that students **internalize** a sense of what energy conservation really means. It follows that this is not a module that should be rushed.

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 1. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 3

Investigation: Projectile Marbles

- ramp of some kind (cardboard, wood, glass, etc.)
- masking tape
- paper
- two marbles
- metre stick or measuring tape

Section 2: Activity 2

Investigation: Conservation of Energy on an Air Table

Part A: Using an air table in a supervised science lab

- an air table in a supervised science lab
- a piece of newsprint paper – approximately 30 cm × 40 cm
- masking tape
- a few books
- a metric ruler

Part B: Using the sample air-table data

- a metric ruler
- a copy of the pull-out page found at the end of the student module booklet (A master for a photocopying is provided for you at the back of this LFM.)

Section 2: Activity 3

Investigation: Properties of a Mass on a Spring

- a spring
- a set of identical masses, each ranging from 100 g to 150 g. (A substitution can be made here with a plastic bag as a holder and anything that comes in packages of about 100 g each. Quarter-pound margarine blocks (113.5 g each) work quite nicely.)
- a measuring tape or metre stick
- a paper clip
- a stand to support the spring
- a stopwatch

Investigation: Gravitational Potential Energy to Spring Potential Energy

- Students are to design this experiment, so the materials list will vary. The materials listed for the previous investigation would be a typical list.

Additional Resources

Each of the following resources can provide additional support and information for the teacher of Physics 30.

Alberta Education. *Senior High Science Teacher Resource Manual*. Edmonton: Dept. of Education, Curriculum Branch, 1992

Giancoli, Douglas C. *Physics*. 3rd ed. Toronto, Ontario: Prentice-Hall Canada Inc., 1991

Hewitt, Paul G. *Conceptual Physics*. Don Mills, Ontario: Addison-Wesley Publishing Company Inc., 1987

Kane, Joseph W., Sternheim, Morton M. *Physics: SI Version*. Toronto, Ontario: John Wiley & Sons Inc., 1980

Martindale, David G., et al. *Fundamentals of Physics: Combined Edition*: D.C. Heath Canada Ltd., 1992

Zitzewitz, Paul W., et al. *Physics: Principles and Problems Teacher Resource Package*. Toronto, Ontario: Maxwell Macmillan Canada Inc., 1992

The Zitzewitz textbook is the one that the ADLC materials wrap around. The teacher resource package, which includes the Teacher Wraparound Edition, are designed to help teachers make the most of the textbook. The resource package includes planning guides, strategies for teaching key concepts, answers to end of chapter problems, suggestions for enrichment and remediation, transparency masters, evaluation instruments, and supplemental lessons.

The Giancoli book is the best teacher reference for the physics concepts, providing explanations, ideas for problems, and applications at the college level.

The Kane and Sternheim book is a college text that is great for the biological applications of physics.

Hewitt's book takes a nonmathematical approach to physics and provides very good explanations of basic concepts at the high school level.

Another high school text is the Martindale book which has a wonderful assortment of problems.

The *Senior High Science Teacher Resource Manual* includes a great variety of ideas to help teachers implement the vision of the new science curriculum.

Possible Media

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	40%
Section 2 Assignment	60%
TOTAL	100%

Section 1: Starting with Energy and Foresight

The way physics fits into the skills of science is introduced in the context of a review on work and energy. Students are also introduced to the use of icons to draw their attention to science skills. Students are encouraged to develop their abilities in science skills. It is a good idea to make posters of the pages explaining the science skills and the levels found in the Appendix of the Module 1 Student Module Booklet. This will be a valuable point of reference as students fine tune their skills throughout the course.

From an instructors view point, there are some important points about the model for assessing the skills of science in this program.

- For students to learn what is meant by the nature and process of science, it is essential that they spend much of their time doing science activities.

These modules have been designed to promote this kind of learning. The activities marked with the science skill icon should not be regarded as supplements – they are an integral part of the program.

- The model for assessing science skills applies to a wide variety of problem-solving activities in science. Examples would include laboratory investigations, library research projects, field surveys, interviews, and any other activity that allows students to become active problem solvers. It would be a mistake to think that the model applies only to laboratory investigations.
- The whole point of this model is to foster the **growth** of students' abilities in the area of science skills. It follows that if you were asked at the end of the course to determine the level at which a student was operating, you should determine the highest consistent level of performance. Consider the following example:

  While taking Physics 30, a student was assessed twelve times on their ability to collect and record information. The teacher kept the following records:

Date	Sept. 8	Oct. 3	Oct. 8	Oct. 19	Nov. 2	Jan. 11	Feb. 15	Mar. 6	Mar. 24	April 16	May 4	May 19
Level of Collecting & Recording	2	2	1	2	3	1	2	3	4	3	2	3

This student seems to be performing at level 3 for the skill of collecting and recording information.

- All six skills need not be assessed at once. You will notice that throughout the Student Module Booklet that only the skills most appropriate to that activity have been identified by the icon. However, there will be some opportunities for students to demonstrate all six skills at once, particularly when they complete a major unit of study.

- It is recommended that you obtain the most recent information on the assessment model for science skills from the Student Evaluation Branch of Alberta Education.

This section mentions to students how important it is that they solve problems using the Physics 30 data sheets, which can be found at the end of the Appendix in the Student Module Booklet for Module 9. A master for photocopying is provided for you at the back of this LFM. These sheets were consistent with the current Physics 30 Data Booklet at the time the distance learning materials were printed. However, it is possible that the Student Evaluation Branch of Alberta Education has since revised or modified this Data Booklet. If at all possible, it is preferable to obtain the most up-to-date Physics 30 Data Booklet and check it against the data sheets provided in the distance learning materials. You can then either ask your students to update their data sheets, or you can obtain the new Physics 30 Data Booklet by contacting the Student Evaluation Branch.

Section 1: Assignment Answer Key (40 marks)

1. a. False The unit of work is the joule. The unit of power is the watt.
   b. True
   c. True
   d. False Work must have been done sometime in order to give something potential energy.
   e. False The energy converts to less usable forms like sound and thermal energy.
   f. False This is backwards! A theory must fit experimental results.
   g. True
   h. False The skills of science are useful in any situation where you are solving a problem.

2. $$\begin{aligned} \text{power} &= \frac{\text{work}}{\text{time}} \\ &= \frac{Fd}{t} \\ &= F\frac{d}{t} \\ &= \text{force} \times \text{speed} \end{aligned}$$

   units: $$\begin{aligned} \text{watts} &= \frac{\text{J}}{\text{s}} \\ &= \frac{\text{N} \bullet \text{m}}{\text{s}} \\ &= \text{N} \bullet \frac{\text{m}}{\text{s}} \end{aligned}$$

3. $m = 55.0\ \text{kg}$
   $d = 10.2\ \text{m}$
   $t = 25.0\ \text{s}$
   $F = ?$
   $P = ?$

   a. $$\begin{aligned} W &= Fd \\ &= mgd \\ &= (55.0\ \text{kg})\left(9.81\ \text{m/s}^2\right)(10.2\ \text{m}) \\ &= 5.50 \times 10^3\ \text{J} \end{aligned}$$

   b. $$\begin{aligned} P &= \frac{W}{t} \\ &= \frac{5.50 \times 10^3\ \text{J}}{25.0\ \text{s}} \\ &= 220\ \text{W} \end{aligned}$$

4. $m = 1200\ \text{kg}$
   $v = 110\ \text{km/h} = 30.56\ \text{m/s}$
   $E_k = ?$

   $$\begin{aligned} E_k &= \frac{1}{2}mv^2 \\ &= \frac{1}{2}(1200\ \text{kg})(30.56\ \text{m/s})^2 \\ &= 5.60 \times 10^5\ \text{J (or 560 kJ)} \end{aligned}$$

5. $m = 3.3\ \text{g} = 3.3 \times 10^{-3}\ \text{kg}$
   $h = 45\ \text{m}$
   $E_p = ?$

   $$\begin{aligned} E_p &= mgh \\ &= \left(3.3 \times 10^{-3}\ \text{kg}\right)\left(9.81\ \text{m/s}^2\right)(45\ \text{m}) \\ &= 1.5\ \text{J} \end{aligned}$$

6. $m = 48.0\ \text{kg}$
$h = 2.50\ \text{m}$
$v = ?$

$$E_{p(top)} = E_{k(bottom)}$$
$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$$
$$v = \sqrt{2gh}$$
$$= \sqrt{2\left(9.81\ \text{m/s}^2\right)\left(2.50\ \text{m}\right)}$$
$$= 7.00\ \text{m/s}$$

7. a. What effect does the height of a ramp have on the distance a car will go after leaving it?

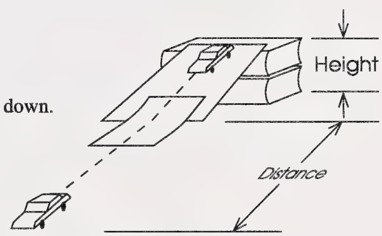
b. Since energy is the ability to do work, a direct relationship exists between height and distance.

$$E_p = \text{work done against friction}$$
$$mgh = F_f d$$
$$\begin{array}{ccccc} d & = & \left(\dfrac{mg}{F_f}\right) & h & \text{zero} \\ \downarrow & & \downarrow & \downarrow & \downarrow \\ y & = & m & x & +b \end{array}$$

c. Materials

- cardboard ramp
- toy car
- measuring tape
- books to adjust the ramp

Procedure

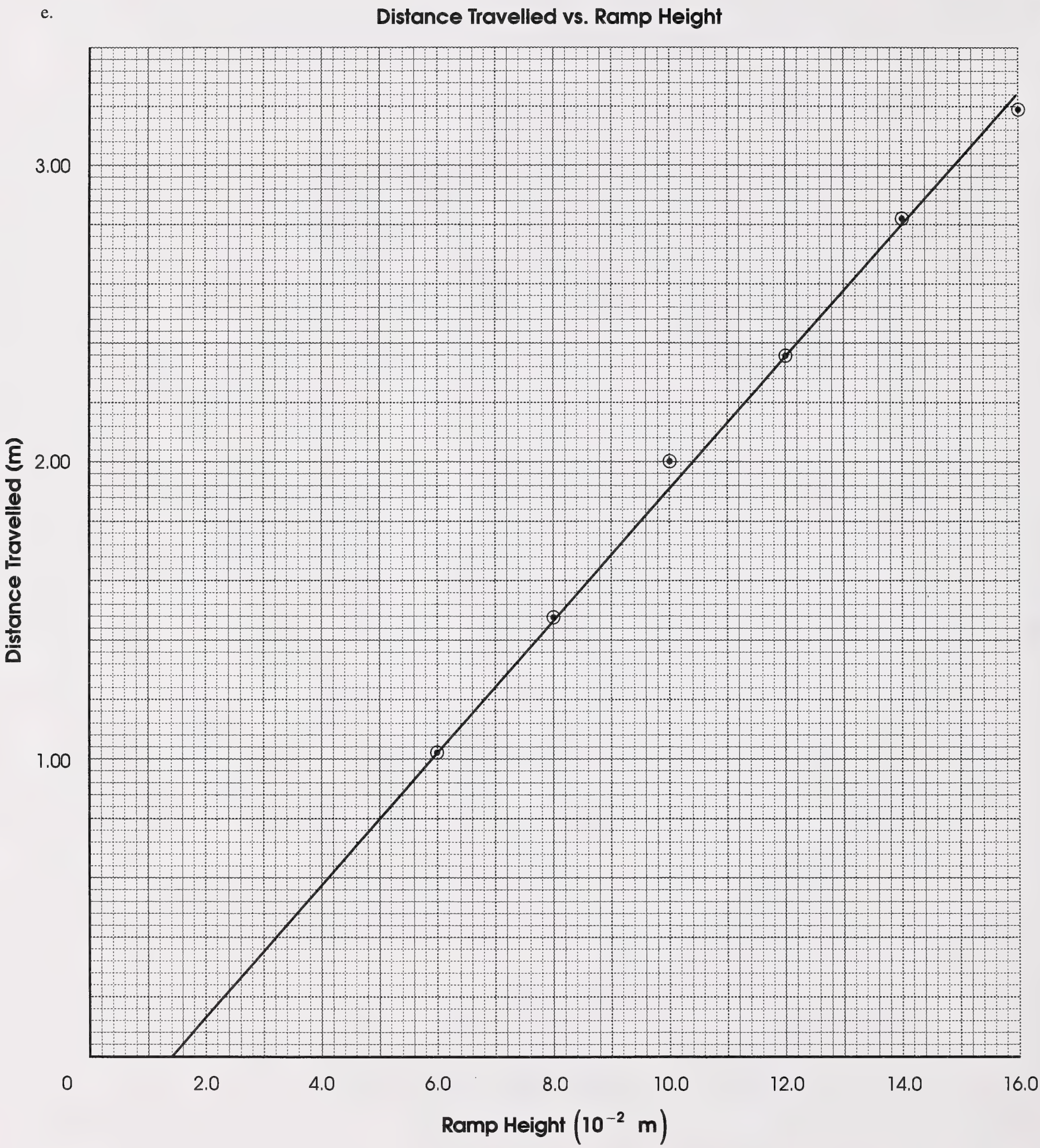


- Set up the ramp as shown. Adjust the height to 6.0 cm and roll the car down.
- Record the ramp height and the distance travelled.
- Repeat this step as you increase the ramp height.
- Graph the distance travelled against the ramp height.

d. If students actually did the experiment, their values will differ from the ones shown here. These values are the same as the sample values provided in the Assignment Booklet.

Ramp Height (cm)	6.0	8.0	10.0	12.0	14.0	16.0
Distance Travelled (m)	1.02	1.47	2.00	2.36	2.83	3.19

e.


Distance Travelled vs. Ramp Height
Distance Travelled (m)
3.00
2.00
1.00
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Ramp Height $(10^{-2}\ m)$

f. $$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{(2.80\ \text{m} - 0.57\ \text{m})}{\left(14.0\times10^{-2}\ \text{m}\right) - \left(4.0\times10^{-2}\ \text{m}\right)}$$
$$= \frac{2.23\ \text{m}}{0.10\ \text{m}}$$
$$= 22\ \ (\text{no unit})$$

$$E_p = \text{work done against friction}$$
$$mgh = F_f d$$
$$d = \left(\frac{mg}{F_f}\right)h \qquad \text{zero}$$
$$y = m \quad x + b$$

Since the slope should equal $\frac{mg}{F_f}$, the force of friction is 22 times smaller than the car's weight. The weight is the normal force from the floor, so $\mu = \frac{F_f}{F_N}$ is $\frac{1}{\text{slope}}$ and equals 0.045. The x-intercept of 1.4 cm suggests that below this value the ramp wouldn't launch the car. It would stay at the top because of friction.

g. The relationship between height and distance is linear and almost direct.

The prediction is falsified if it was as detailed as the one given. The prediction is verified if it predicted only a linear relationship.

h. The car probably doesn't go straight all the time. The floor may be slightly bumpy. The ramp height must be **carefully** measured.

Maybe using a track for the cars would improve the experiment.

Section 2: Exploring Energy Systems

The focus of this section is the law of conservation of energy. Students will be analysing data from investigations with air tables and masses on springs. These experiences are valuable because they provide students with an opportunity to internalize the concepts. The section ends with the development of a problem-solving technique that stresses the similarities among a wide variety of problems. The ideas in this section form the foundation for many concepts in the modules to come.

Section 2: Assignment Answer Key (60 marks)

1. a. The car is powered only by gravity once it is released at the top. Since it loses energy to friction as it goes, it can't reach the height it used to be at. It would be bad to get stuck in a valley and disastrous to not quite make a loop.

   b. A motor drags the car to the top. Electric energy is used to supply the initial gravitational potential energy.

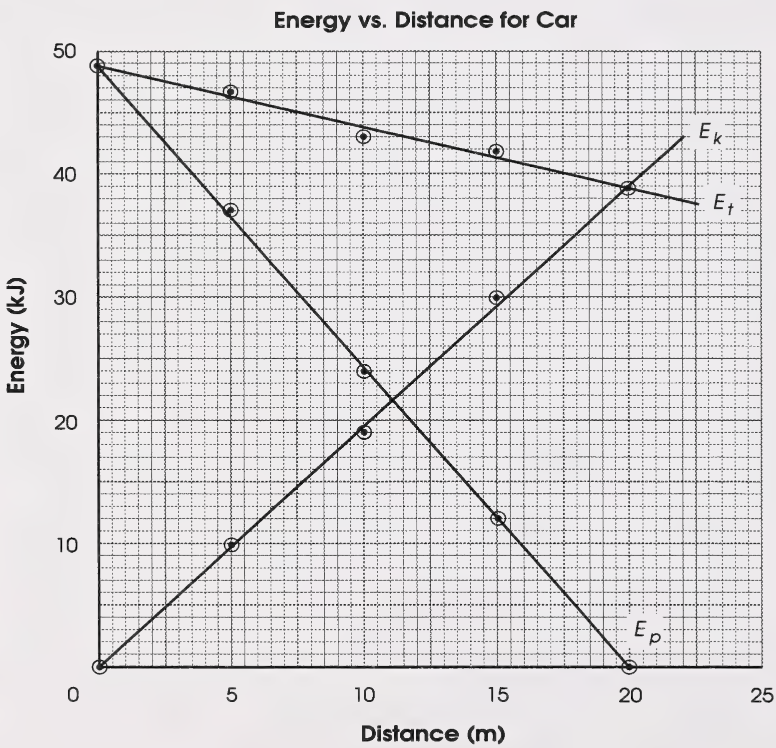
   c. Roller coasters are loud! This means that there is a loss of energy to sound. They also heat up, which is a loss of energy to friction.

2. A standing jump allows a high jumper to convert muscular energy to gravitational potential energy (height). A running start adds kinetic energy to the muscular energy, making more energy available.

3. a. The height above the bottom is $d_b(\sin\theta)$, where d_b is 20.0 m at the top and 0 m at the bottom.

	Height (m)	$E_p = mgh$ (kJ)	$E_k = \frac{1}{2}mv^2$ (kJ)	$E_{(total)}$ (kJ)	Distance from Top of Ramp (m)
Top	4.16	49	0	49	0
	3.12	37	10	47	5.0
	2.08	24	19	43	10.0
	1.04	12	30	42	15.0
Bottom	0	0	39	39	20.0

b.



c. The mechanical energy of the car is not conserved! The total energy is decreasing at a steady rate, which suggests a constant retarding effect on the car. This is probably caused by friction.

d. The slope of the total energy line can be calculated as follows:

$$
\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}} \\
&= \frac{39\ \text{J} - 49\ \text{J}}{20\ \text{m} - 0\ \text{m}} \\
&= \frac{-10\ \text{J}}{20\ \text{m}} \\
&= -0.50\ \text{J/m}
\end{aligned}
$$

This means that the car lost 0.50 J of energy for every metre travelled because work was done against friction to create thermal energy. In other words, 0.50 J of work was done against friction for every metre travelled. Force of friction can be calculated as follows:

$$
\begin{aligned}
W &= F_f d \\
F_f &= \frac{W}{d} \\
&= \frac{0.50\ \text{J}}{1.0\ \text{m}} \\
&= 0.50\ \text{N}
\end{aligned}
$$

4. a. The ball starts at height y_1 and ends at y_2, at the top of the first bounce. In both places $v = 0$ m/s, so $E_k = 0$ J.

Top:

$$
\begin{aligned}
\text{total energy} &= E_p + E_k \\
&= E_p + 0 \\
&= mgy_1
\end{aligned}
$$

Next bounce:

$$
\begin{aligned}
\text{total energy} &= E_p + E_k \\
&= E_p + 0 \\
&= mgy_2
\end{aligned}
$$

The change in energy is $mgy_1 - mgy_2 = mg(y_1 - y_2)$.

b. The "missing" energy has not been accounted for. Some of it is converted to sound and some to thermal energy in the ball and the floor.

5. a. $k = 35$ N/m
$x = 38$ cm $= 0.38$ m
$F = ?$

$$
\begin{aligned}
F &= kx \\
&= (35\ \text{N/m})(0.38\ \text{m}) \\
&= 13\ \text{N}
\end{aligned}
$$

(Note: The minus sign has been omitted since the spring exerts a restoring force of $-kx$.)

b. $k = 35$ N/m
$x = 0.38$ m
$E_p = ?$

$$
\begin{aligned}
E_p &= \frac{1}{2}kx^2 \\
&= \frac{1}{2}(35\ \text{N/m})(0.38\ \text{m})^2 \\
&= 2.5\ \text{J}
\end{aligned}
$$

c. $m = 100\ \text{g} = 0.100\ \text{kg}$
$k = 35\ \text{N/m}$
$x = ?$

weight of 100-g mass:

$$W = mg$$
$$= (0.100\ \text{kg})(9.81\ \text{m/s}^2)$$
$$= 0.981\ \text{N}$$

$$F = kx$$
$$x = \frac{F}{k}$$
$$= \frac{0.981\ \text{N}}{35\ \text{N/m}}$$
$$= 0.028\ \text{m or } 2.8\ \text{cm}$$

d. $m = 100\ \text{g} = 0.100\ \text{kg}$
$k = 35\ \text{N/m}$
$T = ?$

$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$= 2\pi\sqrt{\frac{0.100\ \text{kg}}{35\ \text{N/m}}}$$
$$= 0.34\ \text{s}$$

(This means that it should oscillate 3 times/second.)

6. Many possible answers exist for this question. The following criteria describe some of the possible answers.

   a. any object below the $E_p = 0$ level

   b. any object at rest

   c. any system with friction, any system with an external resistance of any kind, any system that creates thermal energy, sound energy, or light energy

   d. Thermal energy can be created by rubbing or burning a fuel (as in a furnace), etc.

7. $m = 0.100\ \text{kg}$
$d = 0.75\ \text{m}$
$F = 290\ \text{N}$

$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p' + E_k'$$

   a. no air resistance

$$Fd + 0 = mgh' + 0$$
$$h' = \frac{Fd}{mg}$$
$$= \frac{(290\ \text{N})(0.75\ \text{m})}{(0.100\ \text{kg})(9.81\ \text{m/s}^2)}$$
$$= 2.2 \times 10^2\ \text{m}$$

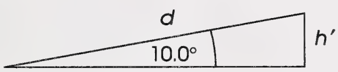
   b. $W' \neq 0$ and $h' = 149\ \text{m}$

$$Fd + 0 = mgh' + 0 + W'$$
$$W' = Fd - mgh'$$
$$= (290\ \text{N})(0.75\ \text{m}) - (0.100\ \text{kg})(9.81\ \text{m/s}^2)(149\ \text{m})$$
$$= 71\ \text{J}$$

8. $m = 0.250$ kg
$x = 0.860$ m
$v' = 5.62$ m/s
$k = ?$

$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p{}' + E_k{}'$$
$$\frac{1}{2}kx^2 + 0 = 0 + \frac{1}{2}mv'^2$$
$$k = \frac{mv'^2}{x^2}$$
$$= \frac{(0.250\text{ kg})(5.62\text{ m/s})^2}{(0.860\text{ m})^2}$$
$$= 10.7\text{ N/m}$$

9. $v = 8.00$ m/s
$\theta = 10.0°$
$v' = 0$ m/s



$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p{}' + E_k{}'$$
$$0 + \frac{1}{2}\cancel{m}v^2 = \cancel{m}gh' + 0$$
$$h' = \frac{v^2}{2g}$$
$$= \frac{(8.00\text{ m/s})^2}{2\left(9.81\text{ m/s}^2\right)}$$
$$= 3.26\text{ m}$$

$$d = \frac{h'}{\sin 10.0°}$$
$$= \frac{3.26\text{ m}}{\sin 10.0°}$$
$$= 18.8\text{ m up the ramp}$$

10. $m = 1200$ kg
$v = 26.0$ m/s
$v' = 17.5$ m/s
$d = 100$ m

$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p{}' + E_k{}' + W$$
$$0 + \frac{1}{2}mv^2 = 0 + \frac{1}{2}mv'^2 + F_f d$$
$$F_f = \frac{\frac{1}{2}mv^2 - \frac{1}{2}mv'^2}{d}$$
$$= \frac{\frac{1}{2}m\left(v^2 - v'^2\right)}{d}$$
$$= \frac{\frac{1}{2}(1200\text{ kg})\left[(26.0\text{ m/s})^2 - (17.5\text{ m/s})^2\right]}{100\text{ m}}$$
$$= 2.22 \times 10^3\text{ N}$$

11. a. The rocket has gravitational potential energy because work was done to lift it into the air. The rocket has kinetic energy because it is moving. The rocket has chemical potential energy because the chemicals are ready to explode.

b. The exploding rocket will produce thermal energy because heat will flow from the chemical reaction of exploding inside to the air. The exploding rocket will also produce light and sound energy.

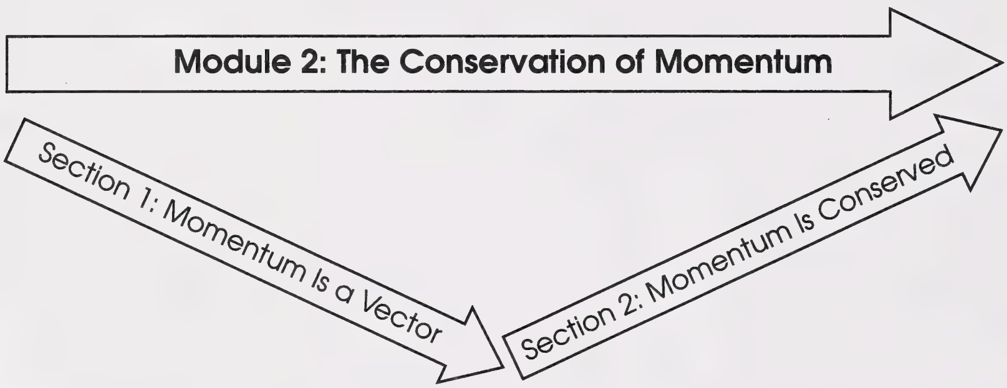
Module 2: The Conservation of Momentum

Overview

This module begins by reviewing the vector concepts first taught in Physics 20. The processes of resolution of vectors and vector addition are extremely important throughout this and later modules.

Next the module proceeds to describe momentum and relate it to Newton's laws of motion. The law of conservation of momentum is explored in one-dimensional and two-dimensional air-puck collisions. Then these concepts are applied in numerous problems.

Finally, the conservation of kinetic energy is described as a determining factor in classifying collisions as elastic (conserved) or inelastic (not conserved).



It will be important for students to have a very clear understanding of the proper use of vector notation. The ADLC materials have adopted a convention that is consistent with the expectations of the Physics 30 diploma exam. Your students will appreciate it if you use the same convention in a consistent way. Unfortunately, the first edition of the textbook does not use this convention. This means that your students will need to be referred to the instructions in the ADLC materials with regard to vector notation.

The guidelines for dealing with vectors follow:

- Physics 20/30 students should be able to add and subtract vector quantities and multiply and divide vector quantities by constants or by scalar quantities.

- Physics 20/30 students should not be expected to multiply and divide vector quantities by other vector quantities. The only time that vectors should be multiplied or divided occurs when both vectors are colinear, in which case they can both be treated as scalars.

The distinctions made by these guidelines are not trivial. The first printing of the Canadian edition of the textbook tends to present equations with vectors multiplied and divided by other vectors. These things have been flagged and addressed in the ADLC materials. If you do not have the first edition, you should explain to your students that the errors discussed have been corrected.

Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 2. Adjust the amount of equipment if more than one individual is involved.

Section 2: Activity 2

Investigation: Conservation of Momentum in One Dimension

Part A

- air table
- velcro strips or putty
- puck launcher (optional)
- newsprint
- ruler for measuring distances
- balance to measure mass of pucks

Part B

- the tear-out page from the Appendix of Module 2 (A master copy of this sheet, which may be used for duplicating, is found at the back of this manual.)

- ruler

Section 2: Activity 4

Investigation: A Two-Dimensional Collision

Part A

- air table with two pucks
- puck launcher (optional)
- newsprint
- ruler for measuring distances
- protractor for measuring angles
- balance to measure mass of pucks

Part B

- the tear-out page from the Appendix of Module 2 (A master copy of this sheet, which may be used for duplicating, is found at the back of this manual.)

- ruler

- protractor

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 2. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Concepts in Mathematics – Vectors: Follow that Arrow* (VC 301 401), *Finding the Resultant* (VC 301 402), *Ordered Pairs* (VC 301 403), *Resolving Without Grids* (VC 301 404). Each of these ten-minute programs is available from ACCESS Network.

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	42%
Section 2 Assignment	58%
TOTAL	100%

Section 1: Momentum Is a Vector

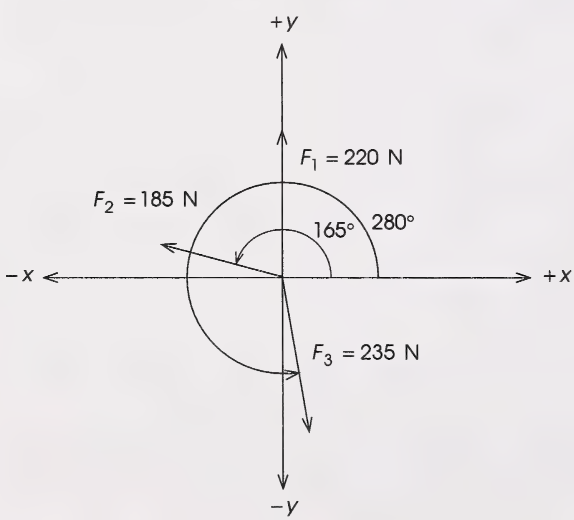
Vectors play an important role throughout Physics 30. The students must be able to resolve vectors into horizontal and vertical components and add two vectors together, even if the angle between them is not 90°.

Momentum is introduced in this section and is related to force, impulse, and Newton's laws of motion.

Note that the video programs listed under Possible Media could be very helpful for weaker students who are having trouble remembering the proper use of vector notation.

Section 1: Assignment Answer Key (42 marks)

1. a.



b. Find all horizontal and vertical components.

$F_1 = 220 \text{ N at } 90°$

$F_{1_x} = (220 \text{ N})(\cos 90°)$
$= 0 \text{ N}$

$F_{1_y} = (220 \text{ N})(\sin 90°)$
$= 220 \text{ N}$

$F_2 = 185 \text{ N at } 165°$

$F_{2_x} = (185 \text{ N})(\cos 165°)$
$= -178.7 \text{ N}$

$F_{2_y} = (185 \text{ N})(\sin 165°)$
$= 47.9 \text{ N}$

$F_3 = 235 \text{ N at } 280°$

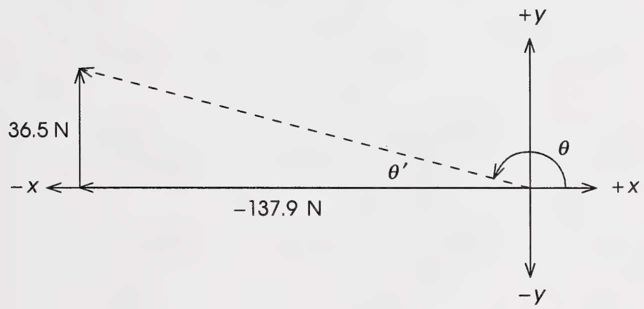
$F_{3_x} = (235 \text{ N})(\cos 280°)$
$= 40.8 \text{ N}$

$F_{3_y} = (235 \text{ N})(\sin 280°)$
$= -231.4 \text{ N}$

Determine the horizontal and vertical vector sums.

$$\begin{aligned} R_x &= F_{1_x} + F_{2_x} + F_{3_x} \\ &= (0 \text{ N}) + (-178.7 \text{ N}) + (40.8 \text{ N}) \\ &= -137.9 \text{ N} \end{aligned}$$

$$\begin{aligned} R_y &= F_{1_y} + F_{2_y} + F_{3_y} \\ &= (220 \text{ N}) + (47.9 \text{ N}) + (-231.4 \text{ N}) \\ &= 36.5 \text{ N} \end{aligned}$$



Determine the magnitude and direction of the resultant.

$$\begin{aligned} R &= \sqrt{R_x{}^2 + R_y{}^2} \\ &= \sqrt{(-137.9 \text{ N})^2 + (36.5 \text{ N})^2} \\ &= 143 \text{ N} \end{aligned}$$

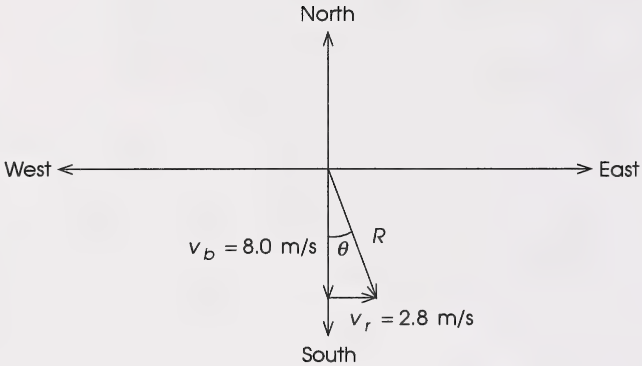
$$\begin{aligned} \tan \theta' &= \frac{\text{opposite}}{\text{adjacent}} \\ &= \frac{36.5 \text{ N}}{137.9 \text{ N}} \\ \theta' &= 15° \end{aligned}$$

$$\begin{aligned} \theta &= 180° - 15° \\ &= 165° \end{aligned}$$

c. $\vec{F}_{net} = m\vec{a}$

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ &= \frac{143 \text{ N}}{125.6 \text{ kg}}, \ 165° \\ &= 1.14 \text{ m/s}^2, \ 165° \end{aligned}$$

2. a.



b. $R^2 = v_b{}^2 + v_r{}^2$

$R = \sqrt{v_b{}^2 + v_r{}^2}$

$= \sqrt{(8.0\text{ m/s})^2 + (2.8\text{ m/s})^2}$

$= 8.5$ m/s

$\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

$= \dfrac{2.8\text{ m/s}}{8.0\text{ m/s}}$

$\theta = 19°$ E of S (or 289°) or S 19° E or equivalent

c. $\vec{p} = m\vec{v}$

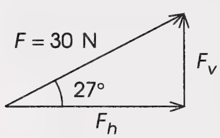
$p = mv$

$= (192\text{ kg})(8.5\text{ m/s})$

$= 1.6 \times 10^3\text{ kg}\bullet\text{m/s}$

The direction for the momentum will be the same as for the velocity, 19° E of S.

3. a.



b. $F_v = |\vec{F}|\sin\theta$

$= (30.0\text{ N})(\sin 27°)$

$= 13.6$ N

$= 14$ N

c. $F_h = |\vec{F}|\cos\theta$

$= (30.0\text{ N})(\cos 27°)$

$= 26.7$ N

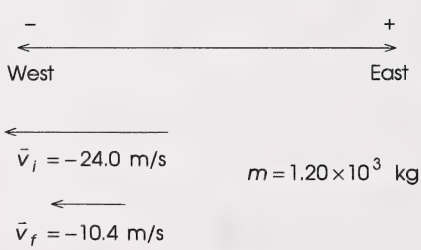
$= 27$ N

d. $W = F_h d$

$= (26.7\text{ N})(125\text{ m})$

$= 3.3 \times 10^3$ J

4. a.



b. $F\Delta t = m\Delta\vec{v}$

$= (1.20 \times 10^3\text{ kg})(-10.4\text{ m/s}) - (-24.0\text{ m/s})$

$= +1.63 \times 10^4\text{ N}\bullet\text{s}$

$= 1.63 \times 10^4\text{ N}\bullet\text{s, east}$

c. $\vec{F}\Delta t = 1.63\times10^{4}\ \text{N}\bullet\text{s, east}$

$$\vec{F} = \frac{1.63\times10^{4}\ \text{N}\bullet\text{s}}{\Delta t}, \text{ east}$$

$$= \frac{1.63\times10^{4}\ \text{N}\bullet\text{s}}{5.50\ \text{s}}, \text{ east}$$

$$= 2.97\times10^{3}\ \text{N, east}$$

5. a. $\Delta\vec{p} = m\Delta\vec{v}$

$$= (0.140\ \text{kg})(-60\ \text{m/s} - 48\ \text{m/s})$$

$$= -15.12\ \text{kg}\bullet\text{m/s}$$

$$= -15\ \text{kg}\bullet\text{m/s}$$

b. $\vec{F}\Delta t = \Delta\vec{p}$

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$$

$$= \frac{-15.12\ \text{kg}\bullet\text{m/s}}{4.0\times10^{-4}\ \text{s}}$$

$$= -3.8\times10^{4}\ \text{N}$$

Section 2: Momentum Is Conserved

The air table is used twice in this section. The use of the air table and the subsequent analysis of the data is an extremely valuable exercise for students. They can examine elastic and inelastic collisions by performing different variations with proper accessories. (Velcro strips and magnetic pucks are useful and allow for analysis of both inelastic and elastic collisions.)

It should be noted that the spark timer operates at extremely high voltages. Thus, there is a danger to students. Caution should be exercised when working with the air table. Another note regarding the air table is the method for levelling. It is easiest to level the table when a puck is on the table and the air is turned on. File cards can be used to shim up the table legs to level the table. When the puck stays relatively stationary, the table is fairly level. If several trials are being performed, the level can be checked periodically.

A powerful tool for teaching momentum conservation and elastic and inelastic collisions is the laserdisc entitled *Physics: Cinema Classics,* available from D.C. Heath Canada Ltd. (through LRDC). In the following example, the use of the laserdisc is described.

Example – Use Disc 3, Side E.

Advance to frame 27012. The mass of a cannon and bullet are provided. Advance to the next frame, 27013. You will notice that the clip you are about to view is filmed at 18 frames per second (fps). Press "play" and the explosion occurs. Advance to frame 27056. Here you see that the next clip (slow motion) is filmed at 8000 fps. This clip can be analysed.

Tape a clear sheet of acetate over the TV screen. Advance to frame 27338. You can see the bullet just emerging from the cannon. Mark the position of both the bullet and cannon on the acetate sheet. Label these marks with the frame number.

Advance to frame 27410 and mark the position of the bullet. Label it 27410 and then advance to frame 28338. At this frame, mark and label the position of the cannon.

Now determine the speed of the bullet and cannon using $v = \frac{d}{t}$. By measuring the length of 0.5 m on frame 27013, you can determine a scale. Use this scale to determine the distance travelled by the bullet (from frame 27338 to 27410) and the cannon (27338 to 28338). The times will be $\frac{(27\,410 - 27\,338)}{8000\ \text{f/s}} = 0.009\ \text{s}$ for the bullet and $\frac{(28\,338 - 27\,338)}{8000\ \text{f/s}} = 0.125\ \text{s}$ for the cannon.

Finally, using the masses given at frame 27012, you can analyse the momentum of each object to verify the law of conservation of momentum.

There are many other excellent experiments that can be performed using this laserdisc. A few of these are listed:

- Rifle and Bullet 28798 – 29599
- Air Table 35987 – 36843
- Pendulum – One Dimension 39342 – 40649
  – Two Dimensions 40662 – 41978
- Billiard Balls 44774 – 46066
- Freight Cars 46180 – 47683

Section 2: Assignment Answer Key (58 marks)

1. Determine the change in the momentum for each toy car.

Car A
$$\begin{aligned} m_A &= 1.2 \text{ kg} \\ \Delta\vec{v}_A &= \vec{v}_A{}' - \vec{v}_A \\ &= 11.2 \text{ m/s} - 1.6 \text{ m/s} \\ &= 9.6 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \Delta\vec{p}_A &= m_A \Delta\vec{v}_A \\ &= (1.2 \text{ kg})(9.6 \text{ m/s}) \\ &= 11.52 \text{ kg} \bullet \text{m/s} \\ &= 12 \text{ kg} \bullet \text{m/s} \end{aligned}$$

Car B
$$\begin{aligned} m_B &= 1.8 \text{ kg} \\ \Delta\vec{v}_B &= \vec{v}_B{}' - \vec{v}_B \\ &= 3.6 \text{ m/s} - 10.0 \text{ m/s} \\ &= -6.4 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \Delta\vec{p}_B &= m_B \Delta\vec{v}_B \\ &= (1.8 \text{ kg})(-6.4 \text{ m/s}) \\ &= -11.52 \text{ kg} \bullet \text{m/s} \\ &= -12 \text{ kg} \bullet \text{m/s} \end{aligned}$$

One of the conditions that determines an isolated system is that $\Delta\vec{p}_1 = -\Delta\vec{p}_2$ in a collision, which is shown to be true here. Thus, you can conclude that the two cars are an isolated system.

2. Momentum will be conserved in both cases. Since the rubber bullet changes its momentum more than the aluminum bullet, it must also provide a greater change in momentum to the block $\left(\Delta\vec{p}_{bullet} = -\Delta\vec{p}_{block}\right)$. Therefore, the rubber bullet makes the block move faster.

3. a.
$$\sum E_{top} = \sum E_{bottom}$$
$$E_{p_{top}} + E_{k_{top}} = E_{p_{bottom}} + E_{k_{bottom}}$$
but $E_{k_{top}} = 0$ and $E_{p_{bottom}} = 0$ by making the reference level the bottom of the hill, so
$$\begin{aligned} E_{p_{top}} &= E_{k_{bottom}} \\ \cancel{m}gd &= \frac{1}{2}\cancel{m}v^2 \\ v &= \sqrt{2gd} \\ &= \sqrt{2\left(9.81 \text{ m/s}^2\right)(2.2 \text{ m})} \\ &= 6.57 \text{ m/s} \\ &= 6.6 \text{ m/s} \end{aligned}$$

b.

$$- \longleftrightarrow +$$

Opposite direction ... Forwards

$\vec{v}_J = +6.57$ m/s $\longrightarrow$ $\vec{v}_s = +6.57$ m/s

$\vec{v}_J{}' = +5.8$ m/s $\longrightarrow$ $\vec{v}_s{}' = ?$

$$\sum \vec{p}_{before} = \sum \vec{p}_{after}$$

$$m_J \vec{v}_J + m_s \vec{v}_s = m_J \vec{v}_J{}' + m_s \vec{v}_s{}', \text{ but } \vec{v}_J = \vec{v}_s = v$$

$$\text{so } (m_J + m_s)\vec{v} = m_J \vec{v}_J{}' + m_s \vec{v}_s{}'$$

$$\vec{v}_s{}' = \frac{(m_J + m_s)\vec{v} - m_J \vec{v}_J{}'}{m_s}$$

$$= \frac{(40.0 \text{ kg} + 3.0 \text{ kg})(+6.57 \text{ m/s}) - (40.0 \text{ kg})(+5.8 \text{ m/s})}{3.0 \text{ kg}}$$

$$= +16.8 \text{ m/s}$$

$$= +17 \text{ m/s}$$

The velocity of the skateboard would be 17 m/s in the original direction (forwards).

c. Work done = Change in kinetic energy of the skateboard

$$W = \frac{1}{2} m_s v_s{}'^2 - \frac{1}{2} m_s v_s{}^2$$

$$= \frac{1}{2} m_s \left(v_s{}'^2 - v_s{}^2 \right)$$

$$= \frac{1}{2}(3.0 \text{ kg})\left((16.8 \text{ m/s})^2 - (6.57 \text{ m/s})^2\right)$$

$$= 159 \text{ J}$$

$$= 1.6 \times 10^2 \text{ J}$$

Jerry does 1.6×10^2 J of work on the skateboard.

4. a.

$$- \longleftrightarrow +$$

West ... East

$\vec{v}_A = -6.25$ m/s $\longleftarrow$

$\longrightarrow$ $\vec{v}_B = +7.00$ m/s

b. $$\sum \vec{p}_{before} = \sum \vec{p}_{after}$$

$$m_A \vec{v}_A + m_B \vec{v}_B = (m_A + m_B)\vec{v}'$$

$$\vec{v}' = \frac{m_A \vec{v}_A + m_B \vec{v}_B}{(m_A + m_B)}$$

$$= \frac{(8.30\times10^4 \text{ kg})(-6.25 \text{ m/s}) + (9.64\times10^4 \text{ kg})(+7.00 \text{ m/s})}{(8.30\times10^4 \text{ kg} + 9.64\times10^4 \text{ kg})}$$

$$= +0.8698 \text{ m/s}$$

$$= 0.870 \text{ m/s, east}$$

c. According to Newton's third law of motion and the law of conservation of momentum, the magnitude of the impulse is the same on each car.

$$\vec{F}_{AB}\Delta t = m_B \Delta \vec{v}_B$$

$$= (9.64\times10^4 \text{ kg})(0.870 \text{ m/s} - 7.00 \text{ m/s})$$

$$= -5.91\times10^5 \text{ N}\bullet\text{s}$$

The magnitude of the impulse will be 5.91×10^5 N•s on each car.

d. The collision is completely inelastic since the two freight cars join together. The process of joining together always results in mechanical energy transforming into heat and sound.

e. $$\sum E_{k\,before} = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$$

$$= \frac{1}{2}(8.30\times10^4 \text{ kg})(6.25 \text{ m/s})^2 + \frac{1}{2}(9.64\times10^4 \text{ kg})(7.00 \text{ m/s})^2$$

$$= 3.98\times10^6 \text{ J}$$

$$\sum E_{k\,after} = \frac{1}{2}(m_A + m_B)v^2$$

$$= \frac{1}{2}(8.30\times10^4 \text{ kg} + 9.64\times10^4 \text{ kg})(0.8698 \text{ m/s})^2$$

$$= 6.79\times10^4 \text{ J}$$

$$\text{Loss of } E_k = 3.98\times10^6 \text{ J} - 6.79\times10^4 \text{ J}$$

$$= 3.91\times10^6 \text{ J}$$

$$\text{percent loss} = \frac{3.91\times10^6 \text{ J}}{3.98\times10^6 \text{ J}}\times100\%$$

$$= 98\%$$

This definitely verifies the answer in question 4.d. since almost all of the kinetic energy is lost. This collision is completely inelastic.

5. a.

$m_s = 32\text{ g}$ $\qquad \vec{v}_s = +24\text{ cm/s}$

$\vec{v}_s{}' = ?$

$m_g = 15\text{ g}$ $\qquad \vec{v}_g = 0\text{ cm/s}$

$\vec{v}_g{}' = +30\text{ cm/s}$

b. $\sum \vec{p}_{before} = \sum \vec{p}_{after}$

$$m_s\vec{v}_s + m_g\vec{v}_g = m_s\vec{v}_s{}' + m_g\vec{v}_g{}' \text{ and } \vec{v}_g = 0$$

$$\therefore\ m_s\vec{v}_s = m_s\vec{v}_s{}' + m_g\vec{v}_g{}'$$

$$\vec{v}_s{}' = \frac{m_s\vec{v}_s - m_g\vec{v}_g{}'}{m_s}$$

$$= \frac{(32\text{ g})(+24\text{ cm/s}) - (15\text{ g})(+30\text{ cm/s})}{32\text{ g}}$$

$$= +9.9\text{ cm/s}$$

The resulting speed is 9.9 cm/s.

c. $$\vec{v}_s{}' = \left(\frac{m_s - m_g}{m_s + m_g}\right)v_s$$

$$= \left(\frac{(32\text{ g}) - (15\text{ g})}{(32\text{ g}) + (15\text{ g})}\right)(24\text{ cm/s})$$

$$= 8.7\text{ cm/s}$$

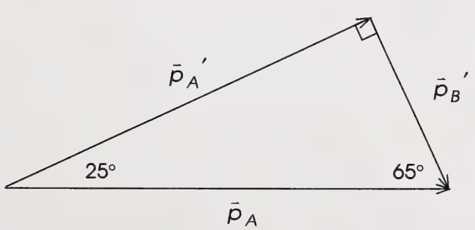
$$\vec{v}_g{}' = \frac{2m_s\vec{v}_s}{m_s + m_g}$$

$$= \frac{2(32\text{ g})(+24\text{ cm/s})}{((32\text{ g}) + (15\text{ g}))}$$

$$= +33\text{ cm/s}$$

If the collision had been perfectly elastic, the steel marble would move ahead at only 8.7 cm/s, while the glass marble would move ahead at 33 cm/s.

6. a.



b. $\vec{p}_A = \vec{p}_A{}' + \vec{p}_B{}'$ or $m_A\vec{v}_A = m_A\vec{v}_A{}' + m_B\vec{v}_B{}'$

c. $\vec{p}_A = m_A \vec{v}_A$
$= (0.165\ \text{kg})(4.2\ \text{m/s})$
$= 0.693\ \text{kg} \bullet \text{m/s}$

$p_A{}' = p_A(\cos 25°)$
$= (0.693\ \text{kg} \bullet \text{m/s})(\cos 25°)$
$= 0.628\ \text{kg} \bullet \text{m/s}$

$p_A{}' = m_A v_A{}'$

$v_A{}' = \dfrac{p_A{}'}{m_A}$
$= \dfrac{0.628\ \text{kg} \bullet \text{m/s}}{0.165\ \text{kg}}$
$= 3.8\ \text{m/s}$

$p_B{}' = p_A(\cos 65°)$
$= (0.693\ \text{kg} \bullet \text{m/s})(\cos 65°)$
$= 0.293\ \text{kg} \bullet \text{m/s}$

$p_B{}' = m_B v_B{}'$

$v_B{}' = \dfrac{\vec{p}_B{}'}{m_B}$
$= \dfrac{0.293\ \text{kg} \bullet \text{m/s}}{0.165\ \text{kg}}$
$= 1.8\ \text{m/s}$

Ball A travels 3.8 m/s, while ball B moves at 1.8 m/s.

7. a. $v_A = \dfrac{d_A}{t_A}$
$= \dfrac{6.35\ \text{cm}}{0.080\ \text{s}}$
$= 79.4\ \text{cm/s}$

$p_A = m_A v_A$
$= (0.550\ \text{kg})(79.4\ \text{cm/s})$
$= 43.7\ \text{kg} \bullet \text{cm/s}$
$\vec{p}_A = 43.7\ \text{kg} \bullet \text{cm/s},\ 0°$

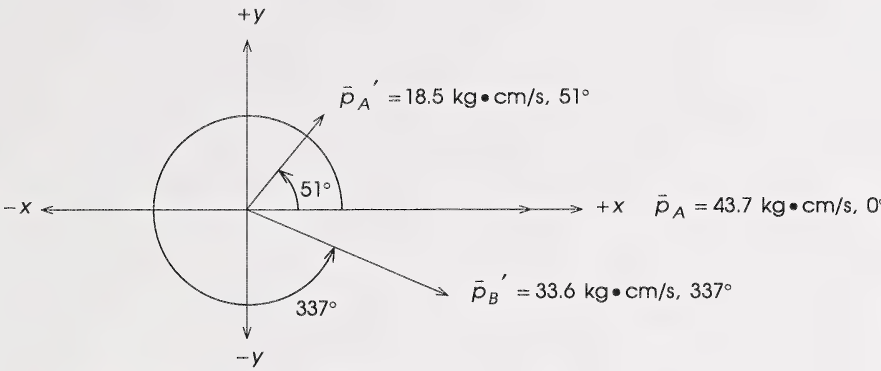
$v_A{}' = \dfrac{d_A{}'}{t_A{}'}$
$= \dfrac{6.05\ \text{cm}}{0.180\ \text{s}}$
$= 33.6\ \text{cm/s}$

$p_A{}' = m_A v_A{}'$
$= (0.550\ \text{kg})(33.6\ \text{cm/s})$
$= 18.5\ \text{kg} \bullet \text{cm/s}$
$\vec{p}_A{}' = 18.5\ \text{kg} \bullet \text{cm/s},\ 51.0°$

$v_B{}' = \dfrac{d_B{}'}{t_B{}'}$
$= \dfrac{11.00\ \text{cm}}{0.180\ \text{s}}$
$= 61.1\ \text{cm/s}$

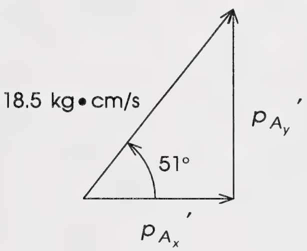
$p_B{}' = m_B v_B{}'$
$= (0.550\ \text{kg})(61.1\ \text{cm/s})$
$= 33.6\ \text{kg} \bullet \text{cm/s}$
$\vec{p}_B{}' = 33.6\ \text{kg} \bullet \text{cm/s},\ 337°$

b.



- Find the components of A and B after the collision.

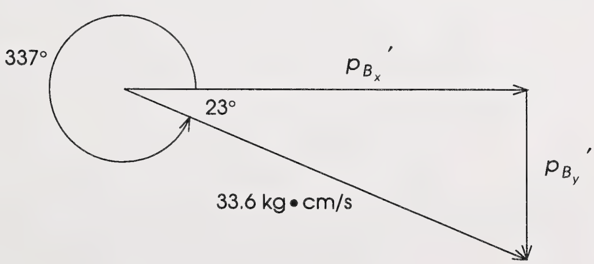
$\vec{p}_A{}' = 18.5 \text{ kg} \bullet \text{cm/s at } 51.0°$



$$\begin{aligned} p_{A_x}{}' &= p(\cos\theta) \\ &= (18.5 \text{ kg} \bullet \text{cm/s})(\cos 51.0°) \\ &= 11.6 \text{ kg} \bullet \text{cm/s} \end{aligned}$$

$$\begin{aligned} p_{A_y}{}' &= p(\sin\theta) \\ &= (18.5 \text{ kg} \bullet \text{cm/s})(\sin 51.0°) \\ &= 14.4 \text{ kg} \bullet \text{cm/s} \end{aligned}$$

$p_B{}' = 33.6 \text{ kg} \bullet \text{cm/s at } 337°$



$$\begin{aligned} p_{B_x}{}' &= p(\cos\theta) \\ &= (33.6 \text{ kg} \bullet \text{cm/s})(\cos 337°) \\ &= 30.9 \text{ kg} \bullet \text{cm/s} \end{aligned}$$

$$\begin{aligned} p_{B_y}{}' &= p(\sin\theta) \\ &= (33.6 \text{ kg} \bullet \text{cm/s})(\sin 337°) \\ &= -13.1 \text{ kg} \bullet \text{cm/s} \end{aligned}$$

- Find the total momentum after the collision.

$$R_x' = p_{A_x} + p_{B_x}$$
$$= (11.6 \text{ kg}\bullet\text{cm/s}) + (30.9 \text{ kg}\bullet\text{cm/s})$$
$$= 42.5 \text{ kg}\bullet\text{cm/s}$$

$$R_y' = p_{A_y} + p_{B_y}$$
$$= (14.4 \text{ kg}\bullet\text{cm/s}) + (-13.1 \text{ kg}\bullet\text{cm/s})$$
$$= 1.3 \text{ kg}\bullet\text{cm/s}$$

$$R = \sqrt{R_x'^2 + R_y'^2}$$
$$= \sqrt{(42.5 \text{ kg}\bullet\text{cm/s})^2 + (1.3 \text{ kg}\bullet\text{cm/s})^2}$$
$$= 42.5 \text{ kg}\bullet\text{cm/s}$$

$$\tan\theta = \frac{R_y}{R_x}$$
$$= \frac{1.3 \text{ kg}\bullet\text{cm/s}}{42.5 \text{ kg}\bullet\text{cm/s}}$$
$$\theta = 1.8°$$

The final resultant is $42.5 \text{ kg}\bullet\text{cm/s}$ at 1.8°. This is extremely close to the initial value of $43.7 \text{ kg}\bullet\text{cm/s}$ at 0°. The difference could be caused by a slightly off-level air table or an initial speed by the stationary puck. Other sources are unlikely or small enough to be discounted, such as friction or air resistance.

c. $$\sum E_{k\,before} = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2, \text{ but } v_B = 0$$
$$= \frac{1}{2}(0.550 \text{ kg})(0.794 \text{ m/s})^2 + 0$$
$$= 0.173\,37 \text{ J}$$
$$= 0.173 \text{ J}$$

$$\sum E_{k\,after} = \frac{1}{2}m_A v_A'^2 + \frac{1}{2}m_B v_B'^2$$
$$= \frac{1}{2}(0.550 \text{ kg})(0.336 \text{ m/s})^2 + \frac{1}{2}(0.550 \text{ kg})(0.611 \text{ m/s})^2$$
$$= 0.133\,71 \text{ J}$$
$$= 0.134 \text{ J}$$

$$\text{percent conserved} = \frac{0.133\,71 \text{ J}}{0.173\,37 \text{ J}} \times 100\%$$
$$= 77.1\%$$

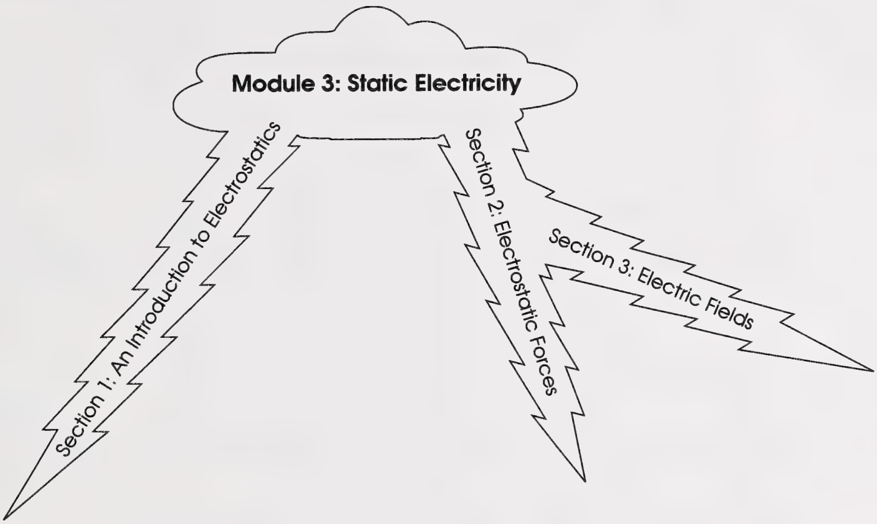
Module 3: Static Electricity

Overview

This module introduces students to the concepts surrounding static electricity. After an introduction that establishes a terminology base, the students probe the nature of the electrostatic force by close analysis of Coulomb's law data. The students then use these experiences to develop the concept of an electric field.

The module also provides lots of practice with solving vector problems, so students can continue to fine tune the skills that they developed in Module 2

It is crucial in this module for students to follow the recommendations regarding the proper notation for forces and fields, as these ideas will be used throughout the rest of the course.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations in Module 3. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 1

Investigation: The Behavior of Charged Objects

- rubber rod and wool or fur
- glass rod and silk
- plastic comb
- four strips of Scotch Brand "Magic"™ tape (each piece is approximately 13 mm × 80 mm)

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 3. Please refer to the list presented in the Module 1 learning facilitator's manual.

Possible Media

Videocassettes – *Electricity*, TV Ontario (Available through ACCESS Network). This video contains six ten-minute programs. The first three programs are used in this module: *Conductors and Insulators*, *Charging and Discharging*, and *Charging by Induction*. These programs are very helpful for getting students started in Section 1.

Laser Videodisc – *Physics*: *Cinema Classics* (1993) – Available from D. C. Heath Canada Ltd. This set of three laser videodiscs has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	30%
Section 2 Assignment	35%
Section 3 Assignment	35%
TOTAL	100%

Section 1: An Introduction to Electrostatics

This section lays the essential conceptual groundwork for the rest of the module. It is vital that students learn the proper terminology and that they have a solid grasp on charging by friction, charging by conduction, and charging by induction. The initial laboratory activity and the video programs are wonderful at helping students achieve this.

Section 1: Assignment Answer Key (30 marks)

1. The three methods of charging an object are charging by rubbing or friction, charging by conduction, and charging by induction.

2. Textbook question 6. a.:

   There are two possibilities. The rod is attracted to the negative comb by induction or the rod is attracted to the negative comb because it is positively charged. Since the rod is an **insulator**, charges do not move about freely on it, so it is more likely to be positive.

   Textbook question 6. b.:

   The rod must be negative.

3. a. The knob is negative.

   b. The leaves are negative.

   c. This is called charging objects by conduction.

   d. The leaves repel because of similar charges.

   e. Bring a negative rod close to the knob. If the leaves diverge even more, they were charged negatively. Another way to test this is to bring a positive rod close to the knob. In this case, the leaves should collapse if they are negative.

4. a. The knob is negative.

   b. The leaves are positive.

   c. This is called charging objects by induction.

   d. The leaves will diverge because they are positively charged because the electrons have been attracted to the knob.

   e. The electroscope seems to have an excess of positive charge in the leaves, so electrons come from the ground to neutralize this excess positive charge in the leaves.

   f. Free electrons redistribute and the electroscope has a net negative charge, so the leaves diverge because of repulsion of excess negative charges.

5. a. The paper atoms become polarized so that one side is negative and the other is positive. The attraction to the rubber rod is greater than the repulsion, therefore attraction occurs.

   b. When the paper attaches to the rod it slowly becomes similarly charged by conduction and eventually repulsion will occur.

6. On a humid day water vapour molecules will absorb charges away from the charged rubber rod.

7. Textbook question 15:

   The lightning rod will be charged by induction from the thundercloud.

   The small ball will have an opposite charge induced on the side closest to the lightning rod. It will move towards the rod and strike the bell. At this point it becomes charged identically to the rod and is repelled. The small ball is then repelled until it strikes the bell attached to the grounded conductor. At this point it loses its excess charge and is attracted once again towards the lightning rod. The cycle then repeats.

8. Step 1: Rub the rubber rod with the fur. The rubber rod will gain a negative charge by friction.

   Step 2: Charge the electroscope with the negative rod by conduction. The electroscope will gain a negative charge and the leaves will diverge.

   Step 3: Bring the charged object close to electroscope. If the leaves diverge more, the object is negative. If the leaves come together, the object is positive.

   The student may also have given the following solution:

   Step 1: Touch the charged object to the electroscope.

   Step 2: Rub the rubber rod with the fur. This will make the rod negatively charged.

   Step 3: Bring the rod near the charged electroscope. If the leaves diverge, the object has a negative charge. If the leaves come together, it is positive.

Section 2: Electrostatic Forces

This section uses Newton's law of universal gravitation as a starting point to encourage students to anticipate Coulomb's law. The investigation is a worthwhile activity because it will help students to maintain their graphing skills while learning about Coulomb's law. Be aware that the first edition of the Canadian edition of the textbook has numerous errors with vector notation that will affect this section. These errors have been explained for the students. If you have a more recent edition of the textbook, some of these errors may have been corrected. The section ends with students incorporating the vector analysis techniques from the previous module into this one.

Section 2: Assignment Answer Key (35 marks)

1. a. $q_1 = -3.00\ \mu\text{C} = -3.00 \times 10^{-6}\ \text{C}$

   $q_2 = +4.00\ \mu\text{C} = 4.00 \times 10^{-6}\ \text{C}$

   $r = 2.00\ \text{m}$

   $F_e = ?$

$$F_e = \frac{kq_1q_2}{r^2}$$

$$= \frac{\left(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(3.00 \times 10^{-6}\ \text{C}\right)\left(4.00 \times 10^{-6}\ \text{C}\right)}{(2.00\ \text{m})^2}$$

$$= 2.70 \times 10^{-2}\ \text{N}$$

b. According to the law of conservation of charge, the total charge remains constant. The total charge before the objects were touched together is $+1.00\ \mu C$. The total after the objects are touched together should be the same. Since the objects touch and they are identical, this total charge is spread evenly over each object. Therefore, each object has $+0.50\ \mu C$ of charge.

$$q_1 = +0.50\ \mu\text{C} = +0.50 \times 10^{-6}\ \text{C} = +5.0 \times 10^{-7}\ \text{C}$$

$$q_2 = +0.50\ \mu\text{C} = +0.50 \times 10^{-6}\ \text{C} = +5.0 \times 10^{-7}\ \text{C}$$

$r = 2.00\ \text{m}$

$F_e = ?$

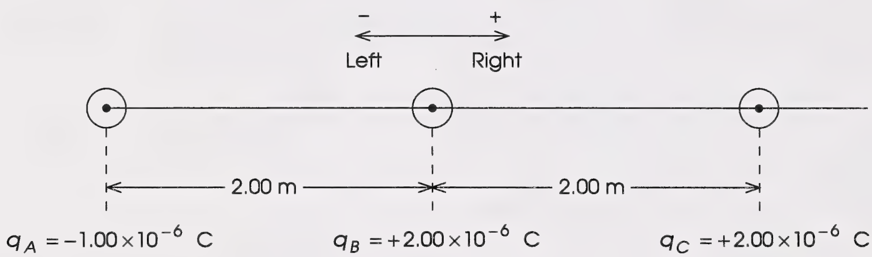
$$F_e = \frac{kq_1q_2}{r^2} = \frac{\left(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(5.0 \times 10^{-7}\ \text{C}\right)\left(5.0 \times 10^{-7}\ \text{C}\right)}{(2.00\ \text{m})^2}$$

$$= 5.62 \times 10^{-4}\ \text{N}$$

$$= 5.6 \times 10^{-4}\ \text{N}$$

Note that this question requires careful thinking about significant digits. Since the original charge was $+1.00\ \text{C}$, this implies that the uncertain digits are $\pm 0.01\ \text{C}$. It follows that this precision should follow through when this charge is halved. Therefore, the halved charges become two siginificant digit measurements: $5.0 \times 10^{-7}\ \text{C}$. The answer should also be rounded to two significant digits, but you may elect not to deduct marks for a three significant digit answer.

2. Step 1: Redraw the diagram and show all the relevant data and a sign convention.



Step 2: Calculate the magnitude of each force.

$$F_{A \to B} = \frac{kq_Aq_B}{r^2} = \frac{\left(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(1.00 \times 10^{-6}\ \text{C}\right)\left(2.00 \times 10^{-6}\ \text{C}\right)}{(2.00\ \text{m})^2}$$

$$= 4.495 \times 10^{-3}\ \text{N}$$

$$F_{C \to B} = \frac{kq_Bq_C}{r^2} = \frac{\left(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(2.00 \times 10^{-6}\ \text{C}\right)\left(2.00 \times 10^{-6}\ \text{C}\right)}{(2.00\ \text{m})^2}$$

$$= 8.99 \times 10^{-3}\ \text{N}$$

Step 3: Using the sign convention, determine the direction of each force.

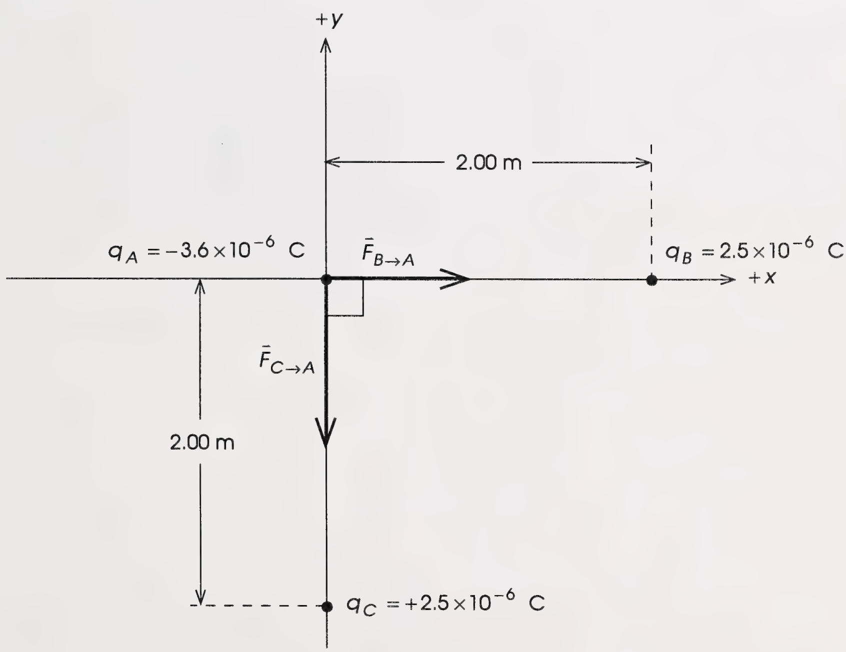
$$F_{A\to B} = 4.495\times10^{-3}\ \text{N, left}$$
$$= -4.495\times10^{-3}\ \text{N}$$

$$F_{C\to B} = 8.99\times10^{-3}\ \text{N, left}$$
$$= -8.99\times10^{-3}\ \text{N}$$

Step 4: Determine the resultant.

$$\begin{aligned}\vec{F}_{net} &= \vec{F}_{A\to B} + \vec{F}_{C\to B}\\ &= \left(-4.495\times10^{-3}\ \text{N}\right)+\left(-8.99\times10^{-3}\ \text{N}\right)\\ &= -1.3485\times10^{-2}\ \text{N}\\ &= -1.35\times10^{-2}\ \text{N}\\ &= 1.35\times10^{-2}\ \text{N, left}\end{aligned}$$

3. Step 1: Redraw the diagram and show a sign convention, all the relevant data, and the directions of the force vectors.



Step 2: Calculate the magnitude of the forces.

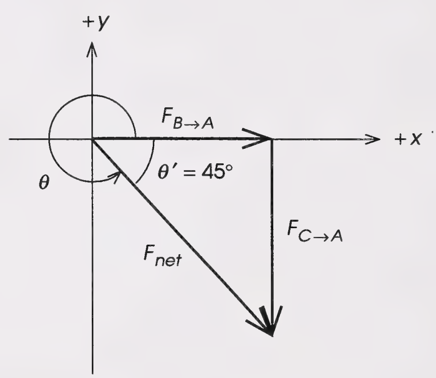
$$F_{C \to A} = \frac{kq_C q_A}{r^2}$$
$$= \frac{\left(8.99 \times 10^9 \ \mathrm{N \bullet m^2/C^2}\right)\left(3.6 \times 10^{-6} \ \mathrm{C}\right)\left(2.5 \times 10^{-6} \ \mathrm{C}\right)}{(2.00 \ \mathrm{m})^2}$$
$$= 2.023 \times 10^{-2} \ \mathrm{N}$$
$$= 2.0 \times 10^{-2} \ \mathrm{N}$$

$$F_{B \to A} = 2.0 \times 10^{-2} \ \mathrm{N}$$

(Since the charges and distances are the same, $F_{B \to A}$ has the same magnitude.)

Step 3: Calculate the magnitude and direction of the resultant.

$$\left|\vec{F}_{net}\right|^2 = \left|\vec{F}_{B \to A}\right|^2 + \left|\vec{F}_{C \to A}\right|^2$$
$$= 2\left|\vec{F}_{B \to A}\right|^2$$
$$= 2\left(2.023 \times 10^{-2} \ \mathrm{N}\right)^2$$
$$= 8.185 \times 10^{-4} \ \mathrm{N}^2$$
$$F_{net} = 2.9 \times 10^{-2} \ \mathrm{N}$$



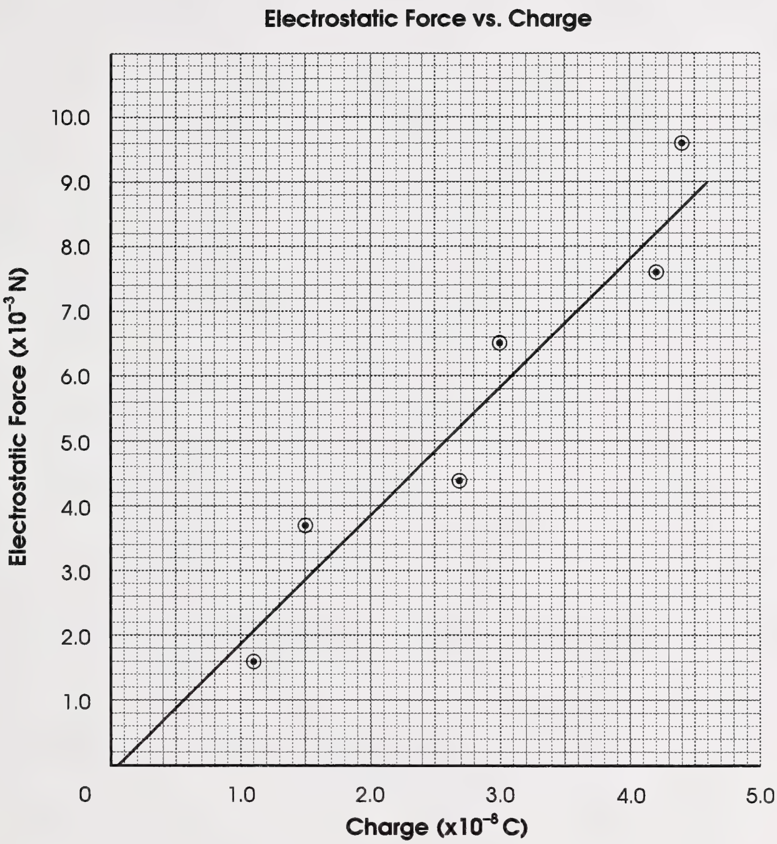
Since the forces are equal, $\theta' = 45°$.

$$\theta = 360° - \theta'$$
$$= 360° - 45°$$
$$= 315°$$

Step 4: State the final answer.

$$\vec{F}_{net} = 2.9 \times 10^{-2} \ \mathrm{N}, \ 315°$$

4. a.



b. $\text{slope} = \frac{\text{rise}}{\text{run}}$

$$= \frac{\left(9.0\times10^{-3}\ \text{N}\right)-(0)}{\left(4.6\times10^{-8}\ \text{N}\right)-\left(0.05\times10^{-8}\ \text{N}\right)}$$

$$= \frac{9.0\times10^{-3}\ \text{N}}{4.55\times10^{-8}\ \text{C}}$$

$$= 1.98\times10^{5}\ \text{N/C}$$

$$= 2.0\times10^{5}\ \text{N/C}$$

Note that a slope of 1.9×10^{5} N/C to 2.0×10^{5} N/C would be considered acceptable as long as it is consistent with the straight line the student produced. The scatter of points means that there is less certainty in this slope value.

c. The diagram indicates that this is a Coulomb's law type of experiment, where the distance of separation was kept constant.

$$F_e = \frac{kq_s q_t}{r^2}$$

$$F_e = \left(\frac{kq_s}{r^2}\right) q_t \quad \text{almost zero}$$

By inspection:

$$\underset{y}{\underset{\downarrow}{F_e}} \; \underset{=}{\underset{}{=}} \; \underset{m}{\underset{\downarrow}{\left(\frac{kq_s}{r^2}\right)}} \; \underset{x}{\underset{\downarrow}{q_t}} \; \underset{+b}{\underset{\downarrow}{}}$$

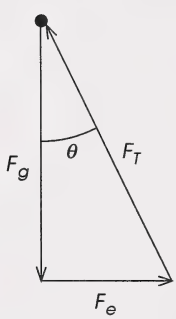
The slope of the graph should equal $\frac{kq_s}{r^2}$.

$$\text{slope} = \frac{kq_s}{r^2}$$

$$\begin{aligned} q_s &= \frac{(\text{slope})r^2}{k} \\ &= \frac{\left(1.98\times10^5 \text{ N/C}\right)(0.45 \text{ m})^2}{\left(8.99\times10^9 \text{ N}\bullet\text{m}^2/\text{C}^2\right)} \\ &= 4.5\times10^{-6} \text{ C} \end{aligned}$$

An answer between 4.3×10^{-6} C and 4.6×10^{-6} C would be considered acceptable if it is consistent with the slope calculation.

d.



Since the test charge is suspended in equilibrium, the vector sum of the electrostatic force and the gravitational force is cancelled by the tension in the thread.

$$\tan\theta = \frac{F_e}{F_g}$$

$$\begin{aligned} F_e &= F_g(\tan\theta) \\ &= mg(\tan\theta) \end{aligned}$$

Section 3: Electric Fields

This section has been designed to use the students' knowledge of gravitational fields from Physics 20 as a bridge to learning about electric fields in Physics 30. You may have to spend more time reviewing the ideas of gravitational field than is presented in the module, but this is well worth the effort. The electric field concept is one of the most difficult for Physics 30 students to internalize, so it makes sense for them to be well versed in the nature of gravitational fields first.

The section ends with students picturing electric fields by drawing electric field lines. This skill, and the use of electric fields in general, will be used often throughout the rest of the course.

Section 3: Assignment Answer Key (35 marks)

1. a. $q = -4.27\times10^{-8}\ \text{C}$

$F_e = 7.91\times10^{-4}\ \text{N}$

$|\vec{E}| = ?$

$$|\vec{E}| = \frac{F_e}{q} = \frac{7.91\times10^{-4}\ \text{N}}{4.27\times10^{-8}\ \text{C}} = 1.85\times10^{4}\ \text{N/C}$$

b. The direction of the electric field is defined to be the direction that a positive test charge would be forced. Since the negative charge in this question is forced north, the direction of the electric field must be south.

2. a. $q = 20\ \text{C}$

$n = ?$

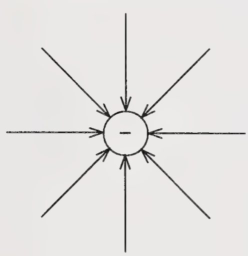
$1\text{e} = 1.60\times10^{-19}\ \text{C}$

$$\frac{1\text{e}}{1.60\times10^{-19}\ \text{C}} = \frac{n}{20\ \text{C}}$$

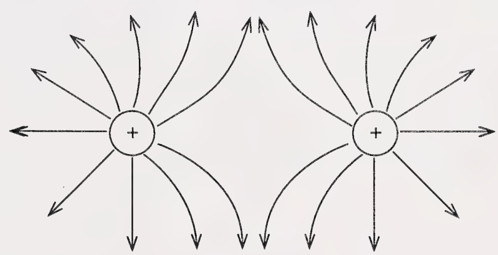
$$n = \frac{(1\text{e})(20\ \text{C})}{\left(1.60\times10^{-19}\ \text{C}\right)} = 1.25\times10^{20}\ \text{electrons} = 1.3\times10^{20}\ \text{electrons}$$

b. The path of a lightning bolt looks jagged because the negative discharge is deflected by pockets of positive ions in the atmosphere. Since these pockets are randomly distributed, the path of the lightning has a random and jagged appearance.

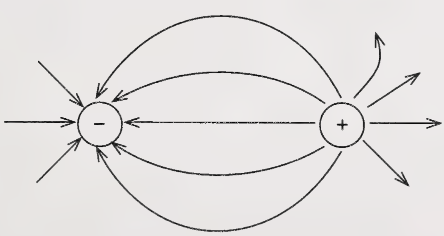
3. a.



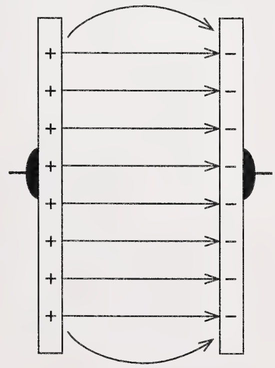
b.



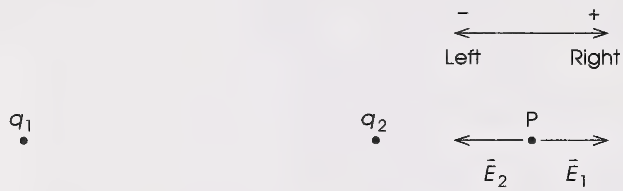
c.



d.



4. Step 1: Redraw the diagram with point charges showing the direction of each of the field vectors.



Step 2: Calculate the magnitude and then the direction of each of the electric field vectors.

$$q_1 = +6.00\ \mu\text{C} = 6.00\times10^{-6}\ \text{C}$$
$$r = 3.00\ \text{m}$$
$$|\vec{E}_1| = ?$$

$$|\vec{E}_1| = \frac{kq_1}{r^2}$$
$$= \frac{\left(8.99\times10^{9}\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(6.00\times10^{-6}\ \text{C}\right)}{(3.00\ \text{m})^2}$$
$$= 5.993\times10^{3}\ \text{N/C}$$

$$\vec{E}_1 = 5.993\times10^{3}\ \text{N/C, right}$$
$$= +5.993\times10^{3}\ \text{N/C}$$

$$q_2 = -3.00\ \mu\text{C} = -3.00\times10^{-6}\ \text{C}$$
$$r = 1.00\ \text{m}$$
$$|\vec{E}_2| = ?$$

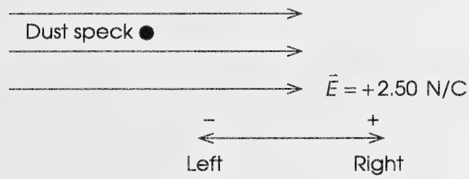
$$|\vec{E}_2| = \frac{kq_2}{r^2}$$
$$= \frac{\left(8.99\times10^{9}\ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(3.00\times10^{-6}\ \text{C}\right)}{(1.00\ \text{m})^2}$$
$$= 2.697\times10^{4}\ \text{N/C}$$

$$\vec{E}_2 = 2.697\times10^{4}\ \text{N/C, left}$$
$$= -2.697\times10^{4}\ \text{N/C}$$

Step 3: Find the resultant electric field.

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$
$$= \left(+5.993\times10^{3}\ \text{N/C}\right) + \left(-2.697\times10^{4}\ \text{N/C}\right)$$
$$= -2.0977\times10^{4}\ \text{N/C}$$
$$= -2.10\times10^{4}\ \text{N/C}$$
$$= -2.10\times10^{4}\ \text{N/C, left}$$

5. a. This solution should be given with a sign convention to describe the directions of the vectors.



$$q = 13.0\ \mu\text{C} = 13.0 \times 10^{-6}\ \text{C}$$
$$= 1.30 \times 10^{-5}\ \text{C}$$
$$m = 5.25\ \text{mg} = 5.25 \times 10^{-6}\ \text{kg}$$
$$|\vec{E}| = 2.50\ \text{N/C}$$
$$a = ?$$

$$F_{net} = F_e$$
$$ma = |\vec{E}|q$$
$$a = \frac{|\vec{E}|q}{m}$$
$$= \frac{(2.50\ \text{N/C})(1.30 \times 10^{-5}\ \text{C})}{5.25 \times 10^{-6}\ \text{kg}}$$
$$= 6.19\ \text{m/s}^2$$
$$\vec{a} = +6.19\ \text{m/s}^2$$

The acceleration will be in the same direction as the net force on the particle, or to the right.

b.

$$\vec{a} = +6.19\ \text{m/s}^2$$
$$\vec{v}_i = 0\ \text{m/s}$$
$$t = 2.00\ \text{s}$$
$$\vec{v}_f = ?$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$
$$\vec{a} = \frac{\vec{v}_f}{t}$$
$$\vec{v}_f = \vec{a}t$$
$$= (+6.19\ \text{m/s}^2)(2.00\ \text{s})$$
$$= +12.38\ \text{m/s}$$
$$= +12.4\ \text{m/s}$$

According to the sign convention, the dust speck will have a final velocity of 12.4 m/s to the right.

c.

$$\vec{a} = +6.19\ \text{m/s}^2$$
$$\vec{d} = +1.00$$
$$\vec{v}_i = 0\ \text{m/s}$$
$$t = ?$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$
$$\vec{d} = \frac{1}{2}\vec{a}t^2$$
$$t = \sqrt{\frac{2\vec{d}}{\vec{a}}}$$
$$= \sqrt{\frac{(2)(+1.00\ \text{m})}{(6.19\ \text{m/s}^2)}}$$
$$= \sqrt{0.323\ \text{s}^2}$$
$$t = 0.568\ \text{s}$$

Module 4: Current Electricity

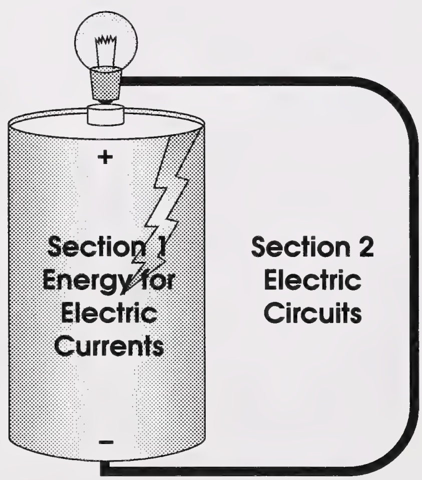
Overview

This module combines many of the key ideas of Modules 1 and 3 to give students a solid understanding of simple circuits involving resistors. The concepts that are introduced for the first time in this module include potential difference (voltage), current, resistance, and Ohm's law. These ideas will be referred to extensively throughout the rest of the course, so it is important that students internalize these things as much as possible. The lab investigations are an excellent way to do this because they bring the theoretical explanations down to Earth. The investigations are not complicated, but it is vital that you try them out yourself first to become acquainted with the particular equipment that is available to you. Try to identify all the possible ways that students could go wrong. This will also help you to be patient when your students are doing the investigations because many of them will either be forgetful or hesitant with the circuits. Be sure to have lots of fuses handy! It is important for the students to have a hands-on experience for another reason. This is one of the best places in the program for students to see how common technology is based on the principles that they have been studying.

If you need to replace or purchase equipment for the first time, it is certainly worth the effort to shop around. You'll have great success if you look under Electronic Equipment and Supplies in the yellow pages for the nearest city. The prices from large urban suppliers will be lower than at a chain of retail stores and they'll be much lower than in the catalogues from scientific supply companies. As an example, a reasonably good quality, simple multimeter (Beckman Industrial: model DM2) can be obtained for $30 to $40 and a universal AC adaptor (Mode Electronics Model 68-514-1) is a very inexpensive power supply at less than $10.00.

It's also possible to make the equipment go further by having groups of students do the investigations, but the danger here is that some individuals will be reduced to spectators. Start planning now to purchase the equipment that you need so that all the students can be directly involved.

Module 4: Current Electricity



Materials and Equipment

The following is a list of materials and equipment for an individual to complete the investigations and activities in Module 4. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 4

Investigation: Measuring Potential Difference and Current for a Resistor

- a multimeter (0 mA to 50 mA, 0 V to 20 V) or an ammeter (0 mA to 50 mA) and a voltmeter (0 V to 20 V)
- a DC power supply capable of producing at least six different output voltages (0 V to 20 V)
- three resistors rated at 0.5 W power handling, 5% tolerance: 1000 Ω, 1500 Ω, 2000 Ω
- four test leads with alligator clips at each end (approximately 50 cm long)

Section 2: Activity 1

Investigation: The Series Circuit

- a DC power supply capable of producing at least six different output voltages (0 V to 20 V)
- a multimeter (0 mA to 20 mA, 0 V to 20 V, 200 Ω to 5000 Ω)
  [If you only have an ammeter (0 mA to 20 mA) and a voltmeter (0 V to 20 V), you will have to modify the procedure.]
- three resistors rated at 0.5 W power handling, 5% tolerance: 510 Ω, 1000 Ω, 1500 Ω
- six test leads with alligator clips at both ends
- masking tape: three pieces, each measuring about $40\ \text{mm} \times 5\ \text{mm}$

Section 2: Activity 2

Investigation: The Parallel Circuit

- a DC power supply capable of producing at least six different output voltages (0 V to 20 V)
- a multimeter (0 V to 20 V, 0 mA to 50 mA, 200 Ω to 5000 Ω)
  [If you only have an ammeter (0 mA to 20 mA) and a voltmeter (0 V to 20 V), you will have to modify the procedure.]
- three resistors rated at 0.5 W power handling, 5% tolerance: 510 Ω, 1000 Ω, 1500 Ω
- six test leads with alligator clips at both ends
- masking tape: three pieces, each measuring about $40\ \text{mm} \times 5\ \text{mm}$

Additional Resources

The same resources listed for Module 1 can provide support and information for teaching Module 4. Please refer to the list for Module 1.

Possible Media

Videocassettes – *Electricity* (TV Ontario) – Available from ACCESS Network. This series of six 10-min programs is a very helpful resource. The last three programs (*Current Electricity*, *Potential Difference*, and *Resistance*) are relevant to this module. Be aware of the fact that these programs use the word *current* to mean electron flow, which is not the standard for Physics 30.

Laser Videodisc – *Physics: Cinema Classics* (1993) – Available from D.C. Heath Canada Ltd. This set of three laser video disks has over 245 classic presentations of physics demonstrations and experiments. Students can gather data from the TV screen, making this an interactive medium. Computer software is also available to interface with the videodisc player.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	60%
Section 2 Assignment	40%
TOTAL	100%

Section 1: Energy for Electric Currents

This section begins with a discussion of objects falling in gravitational fields to prepare students for the analogous situation with electric fields. The role of energy is crucial to the discussion, so many links are made to previous work in Module 1.

After careful development of the idea of potential difference, the students are quickly introduced to the definition of electric current and the proper use of a multimeter. If you have different instruments available to the students, you will have to supplement with instructions that are specific to your equipment.

The section ends with resistance seen as a consequence of a graph of potential difference versus current. The concepts and skills of this section are reinforced with the study of circuits in the next section.

Section 1: Assignment Answer Key (60 marks)

1. Electric potential energy refers to the work done against an electric force to store energy in a system. Electric potential energy is measured in joules, as are all forms of energy. The equation for electric potential energy is as follows:

$$\begin{aligned} E_p &= \text{work done} \\ &= F_e d \end{aligned}$$

Electric potential difference refers to the ratio of the change in an object's potential energy per unit of charge on that object. Electric potential difference is measured in volts. The equation for electric potential difference is as follows:

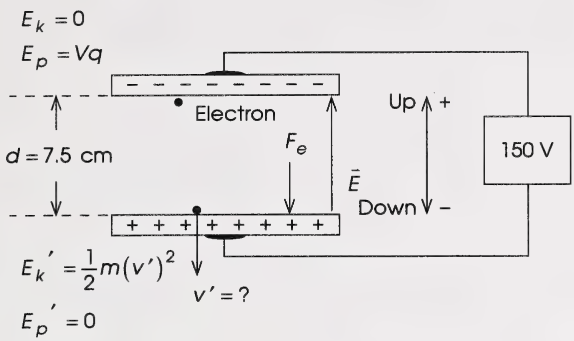
$$V = \frac{E_p}{q}$$

Although both equations deal with electric potential energy, the potential difference is a ratio involving the charge.

2. a. The electron will exhibit accelerated motion due to the electric force exerted by the field between the plates. Since this force is unbalanced, the electron will accelerate in the direction of this force, in accordance with Newton's second law of motion.

   b. The force of gravity will not play a role in this answer because the mass of the electron is so small that the gravitational force can be ignored. The force of air resistance can also be ignored since there is no air in the space between the plates.

c.



$$\sum \text{Energy}_{before} = \sum \text{Energy}_{after}$$

$$E_k + E_p = E_k{}' + E_p{}'$$

$$0 + Vq = \frac{1}{2}m(v')^2 + 0$$

$$(v')^2 = \frac{2Vq}{m}$$

$$v' = \sqrt{\frac{2Vq}{m}}$$

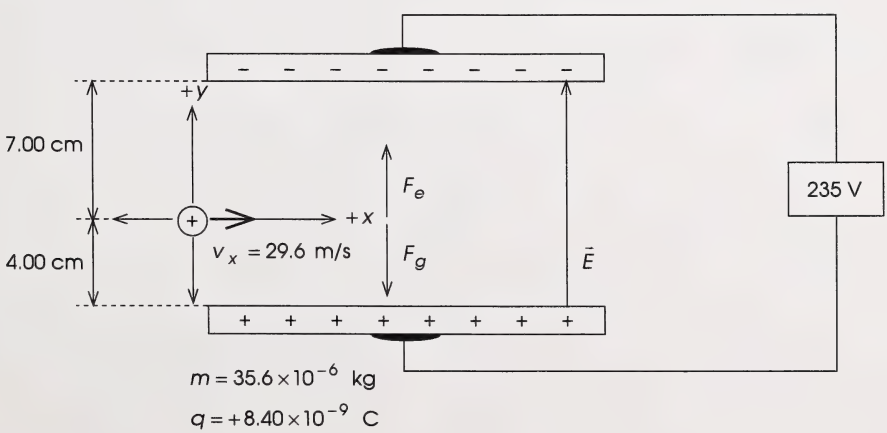
$$= \sqrt{\frac{2(150\ \text{V})(1.60\times10^{-19}\ \text{C})}{(9.11\times10^{-31}\ \text{kg})}}$$

$$= \sqrt{5.27\times10^{13}\ \text{m}^2/\text{s}^2}$$

$$= 7.26\times10^{6}\ \text{m/s}$$

3. a. The force of gravity may be significant because the mass is large enough for gravitational effects to be of the same order as electrostatic effects. The force of air resistance will play no role in the motion because there is no air between the plates.

b.



Consider the forces acting in the direction of the y-axis.

$$\begin{aligned}
\vec{F}_{net} &= \vec{F}_e + \vec{F}_g \\
\left|\vec{F}_{net}\right| &= \left|\vec{F}_e\right| - \left|\vec{F}_g\right| \\
&= \left|\vec{E}\right| q - mg \\
&= \left(\frac{V}{d}\right) q - mg \\
&= \frac{(235\ \text{V})\left(8.40\times10^{-9}\ \text{C}\right)}{(0.1100\ \text{m})} - \left(35.6\times10^{-6}\ \text{kg}\right)\left(9.81\ \text{m/s}^2\right) \\
&= \left(1.7945\times10^{-5}\ \text{N}\right) - \left(3.4924\times10^{-4}\ \text{N}\right) \\
&= -3.313\times10^{-4}\ \text{N} \\
&\doteq -3.31\times10^{-4}\ \text{N}
\end{aligned}$$

The negative direction of this force indicates that the particle will be accelerated towards the lower plate.

c. The particle will move with uniform motion horizontally since no net forces act in this direction. This is in accordance with Newton's first law. The object will accelerate in the vertical direction since this is the direction of the net force. This is in accordance with Newton's second law.

d. $\left|\vec{F}_{net}\right| = -3.313\times10^{-4}\ \text{N} = -3.31\times10^{-4}\ \text{N}$

$m = 35.6\times10^{-6}\ \text{kg}$

$\vec{d} = -4.00\ \text{cm} = -4.00\times10^{-2}\ \text{m}$

$\left(\vec{v}_i\right)_y = 0$

$\left(\vec{v}_f\right)_y = ?$

$t = ?$

- Step 1: Calculate the vertical acceleration.

$$\begin{aligned}
\left|\vec{F}_{net}\right| &= m\vec{a} \\
\vec{a} &= \frac{\left|\vec{F}_{net}\right|}{m} \\
&= \frac{\left(-3.313\times10^{-4}\ \text{N}\right)}{\left(35.6\times10^{-6}\ \text{kg}\right)} \\
&= -9.306\ \text{m/s}^2 \\
&= -9.31\ \text{m/s}^2
\end{aligned}$$

- Step 2: Calculate the time.

$$\begin{aligned}
\vec{d} &= \frac{1}{2}\vec{a}t^2 + \vec{v}_i t \\
\left|\vec{d}\right| &= \frac{1}{2}\left|\vec{a}\right|t^2 + \left|\left(\vec{v}_i\right)\right|_y t \\
\left|\vec{d}\right| &= \frac{1}{2}\left|\vec{a}\right|t^2 + 0 \\
t &= \sqrt{\frac{2\vec{d}}{\vec{a}}} \\
&= \sqrt{\frac{2\left(-4.00\times10^{-2}\ \text{m}\right)}{\left(-9.306\ \text{m/s}^2\right)}} \\
&= 0.092\,72\ \text{s} \\
&= 9.27\times10^{-2}\ \text{s}
\end{aligned}$$

4. a. The increase of the angle indicates that the magnitude of the electrostatic force must be increasing. This is consistent with Coulomb's law, which states that there is an inverse square relationship between the distance of separation and the electrostatic force.

b. Since the distance changed by a factor of $\frac{1}{2}$, the electrostatic force should change by a factor of 4. This is because the inverse square of $\frac{1}{2}$ is $4\left(\frac{1}{\left(\frac{1}{2}\right)^2}=(2)^2=4\right)$, in accordance with Coulomb's law.

c. The potential difference in this case is equal to the change in the potential energy between the globe and the small object divided by the charge of the small object. Work is done against the electrostatic force when the object is moved from position 1 to position 2, so the potential energy increases and so does the electric potential.

d. The problem with this method has to do with the fact that the magnitude of the electric field, $\left|\vec{E}\right|$, is continually changing as the small object is moved from position 1 to position 2. Therefore, the magnitude of the electric field at position 1, $\left|\vec{E}\right|_1=\frac{kq_{\text{globe}}}{(r_1)^2}$, cannot be used in the equation as if it was constant. The equation $V=\left|\vec{E}\right|d$ was derived for the special case of the uniform electric field (constant magnitude) that exists between two parallel plates. This equation should not be used in this situation. This equation also implies that any distance will have the same effect, when in reality the changes in distance will have a much greater effect when the test charge is close to the source due to the non-uniform electric field.

5. $I=0.15\text{ mA}$
$t=1.5\text{ min}=90\text{ s}$
$q=?$

$$\begin{aligned}I&=\frac{q}{t}\\q&=It\\&=\left(0.15\times10^{-3}\text{ A}\right)(90\text{ s})\\&=0.0135\text{ C}\end{aligned}$$

$$\begin{aligned}0.0135\text{ C}\times\left[\frac{1\text{ electron}}{1.60\times10^{-19}\text{ C}}\right]&=8.44\times10^{16}\text{ electrons}\\&=8.4\times10^{16}\text{ electrons}\end{aligned}$$

The calculator would cause 8.4×10^{16} electrons to flow.

6. a. $V=120\text{ V}$
$I=6.0\text{ A}$
$P=?$
$E=?$
unit cost $=\$0.07/\text{kW}\bullet\text{h}$

$$\begin{aligned}P&=\frac{E}{t}\\E&=Pt\\&=(IV)t\\&=(6.0\text{ A})(120\text{ V})(0.50\text{ h})(365)\\&=(720\text{ W})(182.5\text{ h})\\&=(0.720\text{ kW})(182.5\text{ h})\\&=131.4\text{ kW}\bullet\text{h}\end{aligned}$$

$$\begin{aligned}\text{total cost}&=(\text{units of electrical energy})(\text{unit cost})\\&=(131.4\text{ kW}\bullet\text{h})(\$0.07/\text{kW}\bullet\text{h})\\&=\$9.20\end{aligned}$$

b. Step 1: Calculate the resistance of the hair dryer using the data for Canada.

$V=120\text{ V}$
$I=6.0\text{ A}$
$R=?$

$$\begin{aligned}V&=IR\\R&=\frac{V}{I}\\&=\frac{120\text{ V}}{6.0\text{ A}}\\&=20\ \Omega\end{aligned}$$

Step 2: Calculate the current drawn from the hair dryer in Europe.

$V = 240 \text{ V}$

$R = 20 \ \Omega$

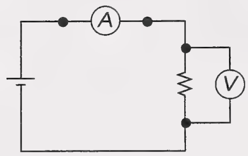
$I = ?$

$$V = IR$$

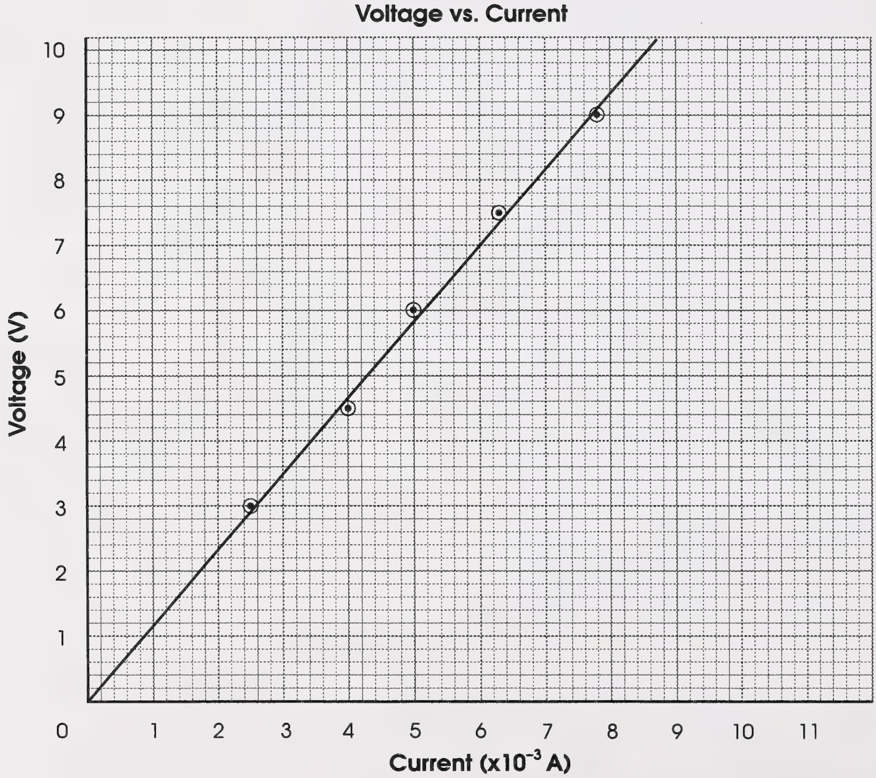
$$I = \frac{V}{R} = \frac{240 \text{ V}}{20 \ \Omega} = 12 \text{ A}$$

This current is twice what the hair dryer was designed to handle. This would probably cause it to burn out due to the heating effects of this high current.

7. a.



b.



c. $$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{(8.4\ \text{V} - 0\ \text{V})}{\left(7.2\times10^{-3}\ \text{A} - 0\ \text{A}\right)}\\ &= \frac{8.4\ \text{V}}{7.2\times10^{-3}\ \text{A}}\\ &= 1167\ \text{V/A}\\ &= 1.2\times10^{3}\ \Omega\end{aligned}$$

Section 2: Electric Circuits

The conceptual development in this section is minimal. The goal here is to reinforce and deepen the understanding of what has already been learned. The lab investigations are well worth the effort because they help students to develop an intuitive understanding of the ideas.

The section ends with the conservation laws. Students are introduced to Kirchhoff's rules as a consequence of the law of conservation of energy and the law of conservation of charge.

Section 2: Assignment Answer Key (40 marks)

1.

$$\boxed{\sum V = 0}$$ Kirchoff's loop rule

↓ Substitute.

$$\boxed{V - V_1 - V_2 - V_3 - V_4 = 0}$$

↓ Rearrange.

$$\boxed{V = V_1 + V_2 + V_3 + V_4}$$

↓ Substitution using Ohm's law. Note that the same current is flowing through each resistor.

$$\boxed{IR_T = IR_1 + IR_2 + IR_3 + IR_4}$$

↓ Divide by *I*.

$$\boxed{R_T = R_1 + R_2 + R_3 + R_4}$$

2.

$$\boxed{\sum I_{in} = \sum I_{out}}$$

Kirchoff's junction rule

Substitute.

$$\boxed{I = I_1 + I_2 + I_3 + I_4}$$

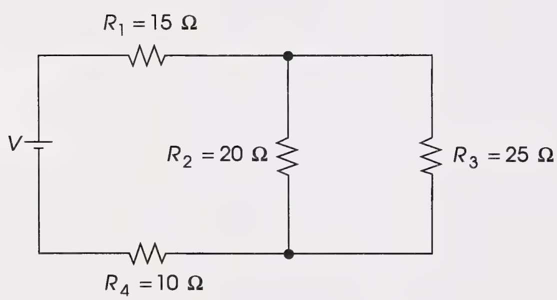
Substitute using Ohm's law. Note that the potential difference is the same across each branch.

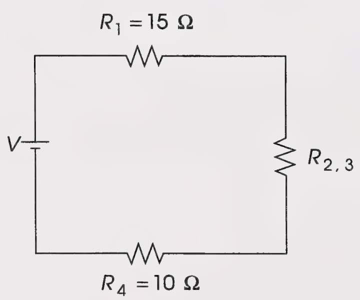
$$\boxed{\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \frac{V}{R_4}}$$

Divide by V.

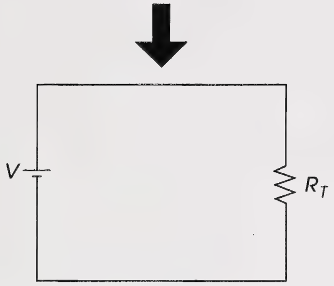
$$\boxed{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

3. a.





$$\begin{aligned}
\frac{1}{R_{2,3}} &= \frac{1}{R_2} + \frac{1}{R_3} \\
&= \frac{1}{20\ \Omega} + \frac{1}{25\ \Omega} \\
&= \left(0.05\ \Omega^{-1}\right) + \left(0.04\ \Omega^{-1}\right) \\
\frac{1}{R_{2,3}} &= \left(0.09\ \Omega^{-1}\right) \\
R_{2,3} &= \frac{1}{\left(0.09\ \Omega^{-1}\right)} \\
&= 11.1\ \Omega \\
&= 11\ \Omega
\end{aligned}$$



$$\begin{aligned} R_T &= R_1 + R_{2,3} + R_4 \\ &= (15\ \Omega) + (11.1\ \Omega) + (10\ \Omega) \\ &= 36.1\ \Omega \\ &= 36\ \Omega \end{aligned}$$

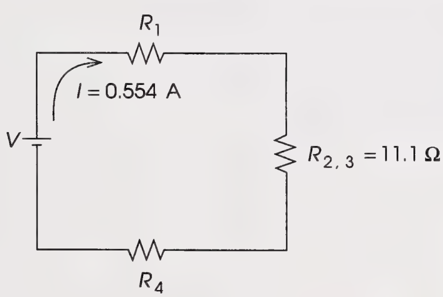
b. $V = 20\ \text{V}$

$R_T = 36.1\ \Omega$

$I = ?$

$$\begin{aligned} V &= IR_T \\ I &= \frac{V}{R_T} \\ &= \frac{20\ \text{V}}{36.1\ \Omega} \\ &= 0.554\ \text{A} \\ &= 0.55\ \text{A} \end{aligned}$$

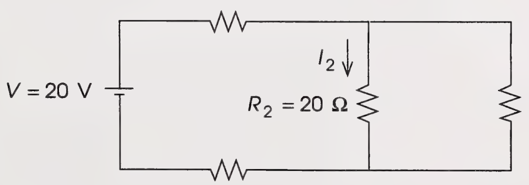
c. Step 1: Calculate the voltage across both R_2 and R_3 using the equivalent circuit from question 3.b.



$$\begin{aligned} V_{2,3} &= IR_{2,3} \\ &= (0.554\ \text{A})(11.1\ \Omega) \\ &= 6.149\ \text{V} \\ &= 6.1\ \text{V} \end{aligned}$$

Note that an answer of 6.2 V is also acceptable if students use exact values.

Step 2: Calculate the current through R_2.



$$\begin{aligned} V_2 &= I_2 R_2 \\ I_2 &= \frac{V_2}{R_2} \\ &= \frac{6.149\ \text{V}}{20\ \Omega} \\ &= 0.307\,45\ \text{A} \\ &= 0.31\ \text{A} \end{aligned}$$

d. $\sum I_{in} = \sum I_{out}$

$$\begin{aligned} I_T &= I_2 + I_3 \\ I_3 &= I_T - I_2 \\ &= (0.554\ \text{A}) - (0.307\ \text{A}) \\ &= 0.247\ \text{A} \\ &= 0.25\ \text{A} \end{aligned}$$

4. a. $R_1 = 2.2\ \text{k}\Omega$

$R_2 = 1.0\ \text{k}\Omega$

$V_T = ?$

$I = ?$

$V_1 = 31\ \text{V}$

$V_2 = ?$

The same current flows through each resistor, so the following calculation applies.

$$\begin{aligned} I_1 &= I_2 \\ \frac{V_1}{R_1} &= \frac{V_2}{R_2} \\ V_2 &= \frac{V_1}{R_1} R_2 \\ &= \frac{(31\ \text{V})(1.0\ \text{k}\Omega)}{(2.2\ \text{k}\Omega)} \\ &= 14.1\ \text{V} \\ &= 14\ \text{V} \end{aligned}$$

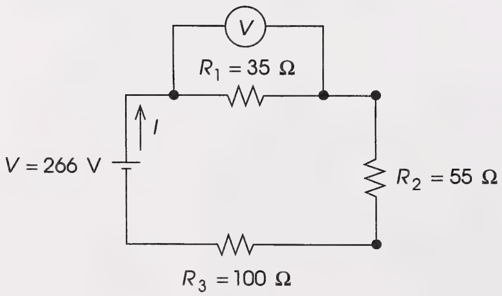
b. $V = ?$

$V_1 = 31\ \text{V}$

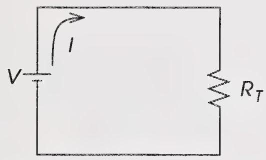
$V_2 = 14.1\ \text{V}$

$$\begin{aligned} \sum V &= 0 \\ V - V_1 - V_2 &= 0 \\ V &= V_1 + V_2 \\ &= (31\ \text{V}) + (14.1\ \text{V}) \\ &= 45.1\ \text{V} \\ &= 45\ \text{V} \end{aligned}$$

5.



Step 1: Find the equivalent resistance for this circuit.



$$\begin{aligned} R_T &= R_1 + R_2 + R_3 \\ &= (35\ \Omega) + (55\ \Omega) + (100\ \Omega) \\ &= 190\ \Omega \end{aligned}$$

Step 2: Find the current flowing through each resistor.

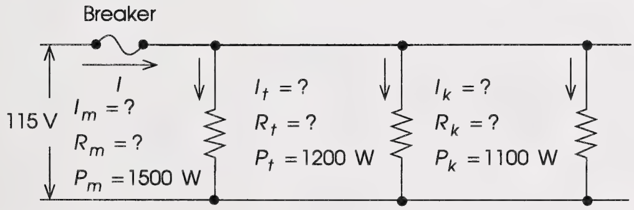
$$\begin{aligned} V &= IR_T \\ I &= \frac{V}{R_T} \\ &= \frac{266\ \text{V}}{190\ \Omega} \\ &= 1.4\ \text{A} \end{aligned}$$

Step 3: Calculate the voltage across R_1.

$I = 1.4$ A
$R_1 = 35\ \Omega$
$V_1 = ?$

$$\begin{aligned} V_1 &= IR_1 \\ &= (1.4\ \text{A})(35\ \Omega) \\ &= 49\ \text{V} \end{aligned}$$

6.



Microwave oven:

$P_m = 1500$ W
$V = 115$ V
$I_m = ?$

$$\begin{aligned} P_m &= I_m V \\ I_m &= \frac{P_m}{V} \\ &= \frac{1500\ \text{W}}{115\ \text{V}} \\ &= 13.0\ \text{A} \end{aligned}$$

Toaster:

$P_t = 1200$ W
$V = 115$ V
$I_t = ?$

$$\begin{aligned} P_t &= I_t V \\ I_t &= \frac{P_t}{V} \\ &= \frac{1200\ \text{W}}{115\ \text{V}} \\ &= 10.4\ \text{A} \end{aligned}$$

Kettle:

$P_k = 1100$ W
$V = 115$ V
$I_k = ?$

$$\begin{aligned} P_k &= I_k V \\ I_k &= \frac{P_k}{V} \\ &= \frac{1100\ \text{W}}{115\ \text{V}} \\ &= 9.57\ \text{A} \end{aligned}$$

$$\begin{aligned} I &= I_m + I_t + I_k \\ &= (13.0\ \text{A}) + (10.4\ \text{A}) + (9.57\ \text{A}) \\ &= 33.0\ \text{A} \end{aligned}$$

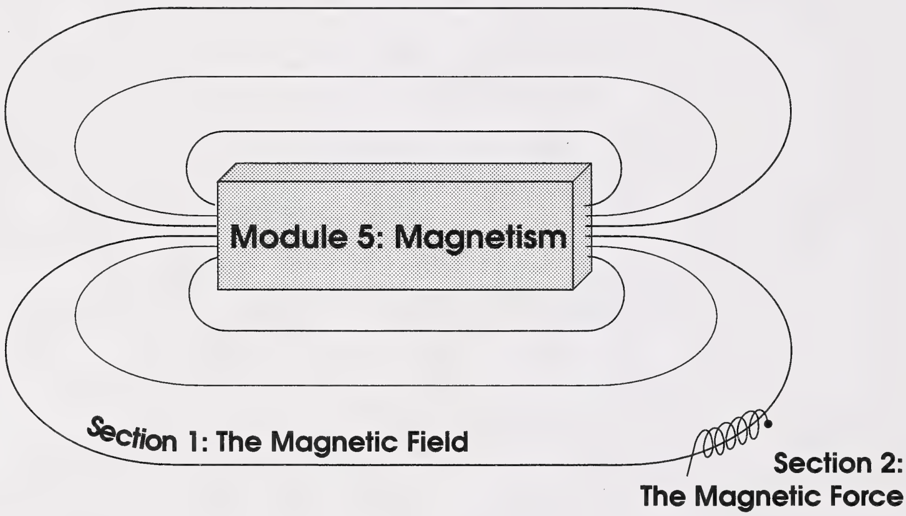
The circuit breaker trips because the total current exceeds 15 A.

Module 5: Magnetism

Overview

This module introduces students to the concepts of the magnetic field and the magnetic force on charged particles. These concepts have a very different nature than previous fields and forces studied by the students because the direction of these vectors is **sideways** rather than towards the source. The result is that students must learn to use hand rules to predict the directions of magnetic forces and fields.

The module is designed to give students as much hands-on experience as possible because the ideas here form the foundation for studying electromagnetic induction in the next module. Because many students find electromagnetic induction quite difficult, it is crucial that the students have a thorough understanding of the hand rules that are presented in this module. One teaching suggestion is to ask the whole group of students to do the hand rules together as you guide them through a lab investigation or the solution to a problem. Don't be surprised if they are hesitant to participate at first because of embarrassment – lots of encouragement from you and a joke or two about learning secret handshakes usually does the trick at breaking the ice.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 5.

Section 1: Activity 2

Investigation: Properties of Bar Magnets

- two bar magnets
- a small magnetic compass
- iron filings
- a sheet of paper or a glass plate that measures approximately 20 cm × 28 cm

Section 1: Activity 4

Investigation: Building Two Air-Core Solenoids

- two PVC terminal adaptors (TA10) with 0.5-inch inside diameters
- two PVC threaded plastic bushings for terminal adaptors with 0.5-inch inside diameters

- piece of stiff paper that measures 12 cm × 12 cm
- 120 g (4 oz) of 28-guage, enamelled magnet wire
- two insulated alligator clips with screw-terminal connectors (one red, one black)
- a wire coat hanger
- a long room or hallway
- a chair with an unupholstered back
- scissors
- Phillips size 2 screwdriver or flat screwdriver (depending on the screws on the alligator clips)
- an old butter knife
- black electric tape

Investigation: Testing Two Air-Core Solenoids

- two air-core solenoids
- a low-voltage power supply
- two electric leads (one black, one red) with alligator clips on both ends
- a multimeter
- a $30\text{-}\Omega$ power resistor
- a 6.0-cm bolt, 0.5 inches in diameter
- a compass

Section 2: Activity 2

Investigation: Force on a Current-Carrying Wire in a Magnetic Field

- air-core solenoid (10 cm by 3 cm)
- current balance attachment for the solenoid
- two ammeters (0 A to 5 A)
- two DC power supplies (0 V to 6 V) with built-in rheostats
- scissors
- connecting wires with alligator clips
- sandpaper (200 to 400 grit)
- 25 to 30 cm of cotton string used for tying parcels (approximately 0.80 mm diameter)
- two knife switches
- centimetre ruler
- electronic balance

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 5. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Electromagnetism,* TV Ontario (Available through ACCESS Network). This set of six 10-min programs is a super resource for this module and the next. The computer animation is very helpful with the hand rules. One thing to watch is that the video programs use the words *current* and *electron flow* interchangeably. Be sure to reinforce to your students that they should be using the terms *electron flow* and *conventional current*.

Only four of the six programs apply directly to this module: *Earth's Magnetic Field, Magnetism and Electron Flow, Domain Theory*, and *The Motor Principle*.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	40%
Section 2 Assignment	60%
TOTAL	100%

Section 1: The Magnetic Field

The magnetic field surrounding permanent bar magnets and current-carrying wires will be demonstrated using iron filings and a compass. Hand rules will then be used to indicate the direction of these magnetic fields. The following suggestions will help the students be more successful with the investigations:

- When students perform the investigation in Activity 2 using the compass, make sure they are at least 1 m away from large metal objects when determining the north pole of the compass.
- For students to learn the application of the hand rules for magnetic fields, it is essential to apply and verify them with the apparatus used in the investigations.
- When students perform the solenoid investigation in Activity 4, leave the circuit switch closed only long enough to make the appropriate observations because heat will build up in the solenoid.
- If you are using a multimeter, it likely has a range overload which is indicated by a "1" or " –1". If this appears on the display, select the next higher range until a value is displayed.
- If a reading for voltage is obtained but no value for current, check the fuse in the back of the multimeter.

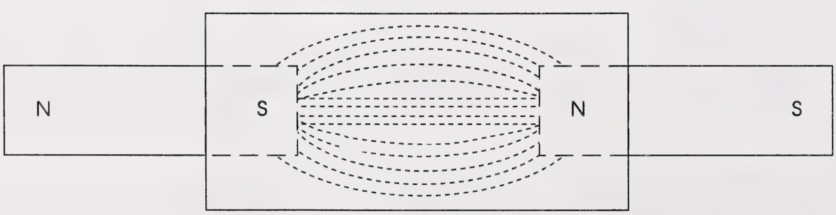
Section 1: Assignment Answer Key (40 marks)

1. a. Answers to this question will vary, but the following sample includes many of the key points that students will mention.

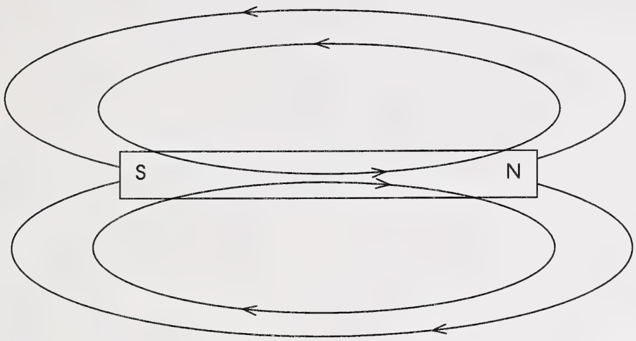
   Prior to the discovery of lodestone, navigation depended on identifying major landmarks and using the sun and the stars. When none of these options were available, navigation would have been almost guesswork. Lodestone presented a new method that worked in a variety of weather conditions. Exploration could now be done more reliably.

   b. Spin-offs of this might include better maps, increased exploration, enhanced barter and trade between different cultures, and a more widespread exchange of information and goods.

2. An attractive force would exist between the poles of the bar magnets. The poles on the bar magnets are labelled.



3.



4. To test if the iron bar is surrounded by an electric field, the following procedure could be used:

- Rub the ebonite rod with the fur, leaving the ebonite rod negatively charged.
- Touch the negatively charged ebonite rod to the electroscope, which will then also become negatively charged. The leaves of the electroscope will diverge.
- Place the negatively charged electroscope near the iron bar.
- If the leaves diverge further, the iron bar is charged negatively. If the leaves collapse, the iron rod is charged positively. In both cases an electric field would surround the iron bar.
- If the electroscope is unaffected when placed near the iron bar, it is not charged and no electric field surrounds the bar.

To test for the presence of a magnetic field surrounding the bar, use the following procedure:

- Place the compass near one end of the iron bar.
- Note the direction in which the north pole of the compass points.
- Move the compass to the opposite end of the iron bar and note the direction in which the compass points.
- If the north pole of the compass points towards one end of the bar and away from the other end, the iron bar is magnetized and is surrounded by a magnetic field.
- If the north pole of the compass points towards the iron bar at both ends, the iron bar is not magnetized, and the compass is simply indicating that the iron bar is a ferromagnetic substance.

5. This data does not support an inverse square law, as shown by the following calculations.

Step 1: Consider the following data points from the chart that is shown in the textbook.

Separation (*d*) (mm)	Force (*F*) (N)
10	3.93
20	0.018
30	0.0028

If the data follows an inverse square law, doubling the distance should reduce the force to one-quarter of its original value, since the inverse square of 2 is $\frac{1}{4}$.

If the data follows an inverse square law, tripling the distance should reduce the force to one-ninth of its original value, since the inverse square of 3 is $\frac{1}{9}$.

Step 2: Test the data points to see if they follow an inverse square law.

$d_1 = 10\ \text{mm}$ $\quad\quad$ $d_2 = 20\ \text{mm}$

$F_1 = 3.93\ \text{N}$ $\quad\quad$ $F_2 = ?$

If it is an inverse square relationship, the following calculation will give the correct value.

$$\begin{aligned} F_2 &= \frac{1}{4}F_1 \\ &= \frac{1}{4}(3.93\ \text{N}) \\ &= 0.983\ \text{N} \end{aligned}$$

This force is much larger than the corresponding value on the data chart.

$d_1 = 10\ \text{mm}$ $\quad\quad$ $d_3 = 30\ \text{mm}$

$F_1 = 3.93\ \text{N}$ $\quad\quad$ $F_3 = ?$

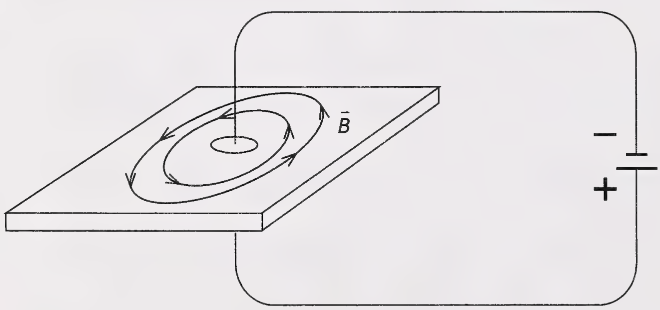
If it is an inverse square relationship, the following calculation will give the correct value.

$$\begin{aligned} F_3 &= \frac{1}{9}F_1 \\ &= \frac{1}{9}(3.93\ \text{N}) \\ &= 0.43\overline{6}\ \text{N} \end{aligned}$$

This force is much larger than the corresponding value on the data chart.

6. The sources of electric fields are charges, the sources of magnetic fields are charges in motion, and the sources of gravitational fields are masses.

7. The hand rule for conductors yields the following answer.



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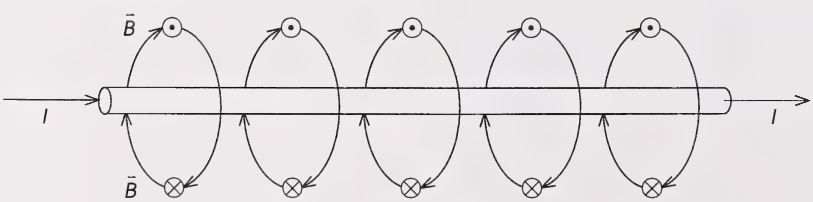
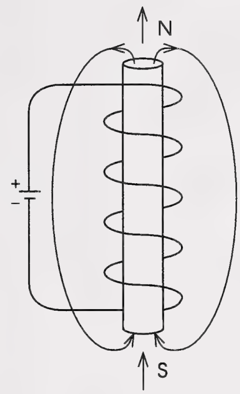


The right-hand rule for coils predicts that the direction of conventional current flow will be in the direction indicated by the arrows in the diagram.

9. Using the hand rule for coils, the top of the electromagnet is the north pole, while the bottom is the south pole.



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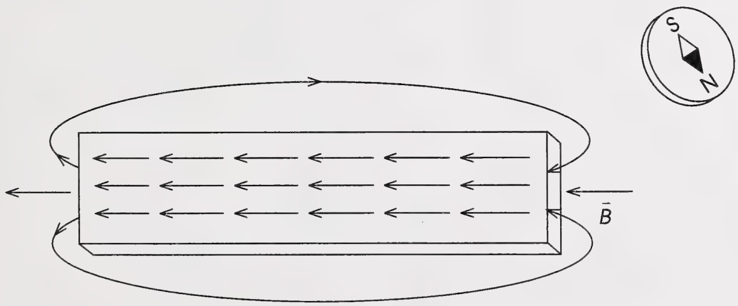
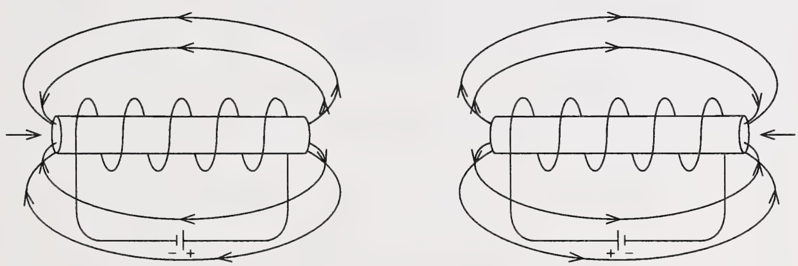


11.



The connections to the voltage supply are opposite to each other. This causes the direction of the field lines to be reversed in these otherwise identical electromagnets.

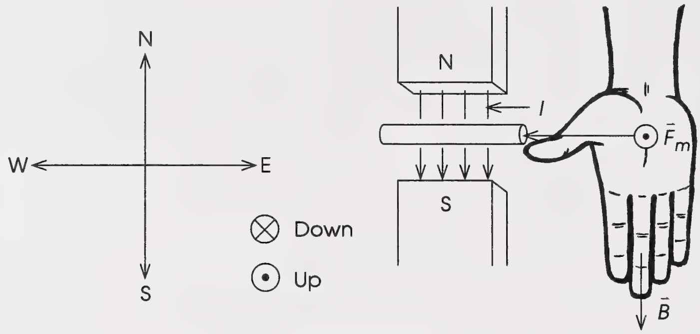
Section 2: The Magnetic Force

After the historical introduction in the first activity, the students should be ready for the current balance investigation in the second activity. This investigation is very helpful for having students internalize the key concepts from the entire module. When students perform this investigation it is important not to leave the current at a high amperage for any prolonged length of time. The last activity provides students with a variety of interesting applications that will help illustrate the relevance of the material and will provide a good opportunity for them to practise the hand rules.

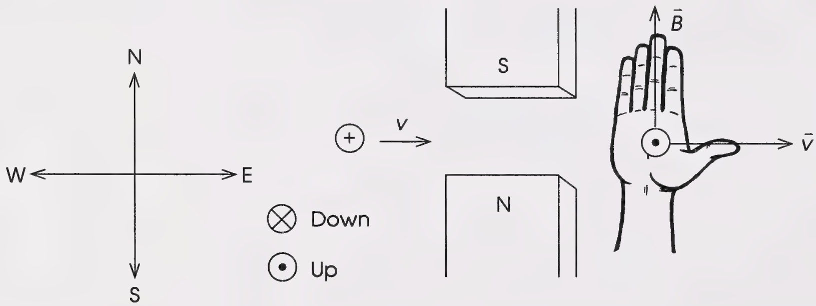
Section 2: Assignment Answer Key (60 marks)

1. Oersted discovered that current-carrying wires generate magnetic fields around themselves. Ampere discovered that a magnetic force is exerted on a current-carrying wire placed within a magnetic field.

2. Application of the right-hand rule for force indicates that the force is directed straight out of the page.



3. When the right-hand rule for force is used for a positive charge entering an external magnetic field, the proton will deflect out of the plane of the page.



4. a. The magnetic force required to balance the string is equal to the force of gravity acting on the string. Calculations are shown for the first and last force values in the data chart.

First value:
$$F_g = F_m$$
$$mg = I\ell B_\perp$$
$$F_m = F_g = mg$$
$$= (3.4\times10^{-4}\ \text{kg})(9.81\ \text{m/s}^2)$$
$$= 3.3\times10^{-3}\ \text{N}$$

Last value:
$$F_m = F_g = (0.6\times10^{-4}\ \text{kg})(9.81\ \text{m/s}^2)$$
$$= 5.88\times10^{-4}\ \text{N}$$
$$= 0.6\times10^{-3}\ \text{N}$$

b. Calculations for the magnetic field of the solenoid are shown.

$$F_m = F_g$$
$$I\ell B_\perp = F_g$$
$$B_\perp = \frac{F_g}{I\ell}$$

Trial 1:
$$B_\perp = \frac{F_g}{I\ell}$$
$$= \frac{3.3\times10^{-3}\ \text{N}}{(8.9\ \text{A})(0.050\ \text{m})}$$
$$= 7.4\times10^{-3}\ \text{T}$$

Trial 2:
$$B_\perp = \frac{F_g}{I\ell}$$
$$= \frac{2.6\times10^{-3}\ \text{N}}{(7.1\ \text{A})(0.050\ \text{m})}$$
$$= 7.3\times10^{-3}\ \text{T}$$

Trial 3: $B_{\perp} = \frac{F_g}{I\ell}$

$= \frac{2.0\times10^{-3}\ \text{N}}{(5.3\ \text{A})(0.050\ \text{m})}$

$= 7.5\times10^{-3}\ \text{T}$

Trial 4: $B_{\perp} = \frac{F_g}{I\ell}$

$= \frac{1.3\times10^{-3}\ \text{N}}{(3.5\ \text{A})(0.050\ \text{m})}$

$= 7.4\times10^{-3}\ \text{T}$

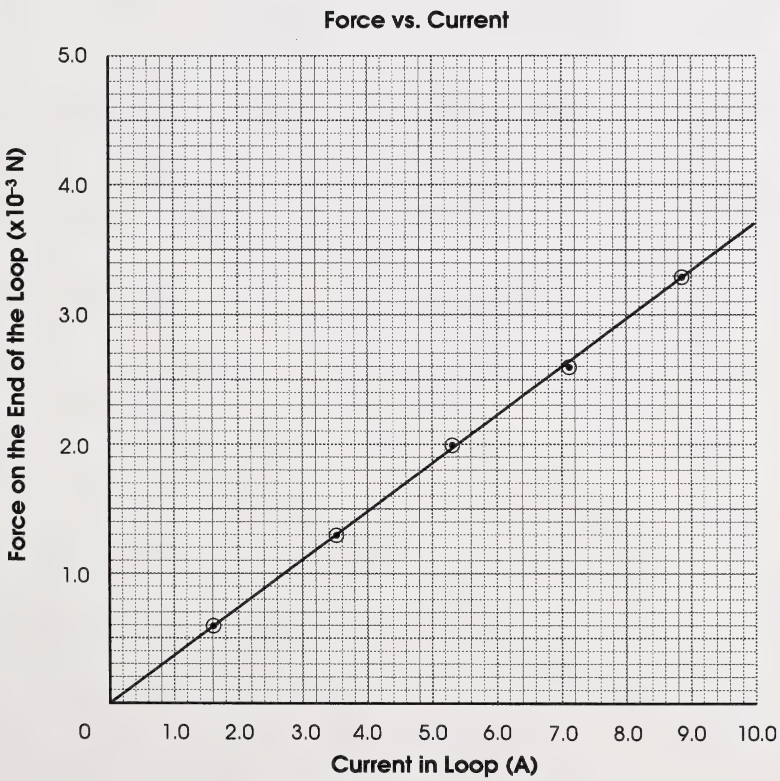
Trial 5: $B_{\perp} = \frac{F_m}{I\ell}$

$= \frac{0.6\times10^{-3}\ \text{N}}{(1.6\ \text{A})(0.050\ \text{m})}$

$= 7.5\times10^{-3}\ \text{T}$

Current in Solenoid (A)	Current in Loop (A)	Mass of String $(\times10^{-4}\ \text{kg})$	Force on End of Loop $(\times10^{-3}\ \text{N})$	Magnetic Field $(\times10^{-3}\ \text{T})$
3.5	8.9	3.4	3.3	7.4
3.5	7.1	2.7	2.6	7.3
3.5	5.3	2.0	2.0	7.5
3.5	3.5	1.3	1.3	7.4
3.5	1.6	0.6	0.6	7.5

c.



d. The force on the loop is directly proportional to the current in the loop.

e.
$$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{\Delta y}{\Delta x}\\ &= \frac{\left(3.0\times10^{-3}\ \text{N}\right)-(0\ \text{N})}{(8.1\ \text{A})-(0\ \text{A})}\\ &= 3.70\times10^{-4}\ \text{N/A}\\ &= 3.7\times10^{-4}\ \text{N/A}\end{aligned}$$

$$\boxed{F_m = I\ell B_\perp}$$

Rearrange.

$$\boxed{F_m = (\ell B_\perp)I}$$

By inspection:

y-intercept is zero

$$\boxed{y = \quad m \quad x + b}$$

The slope corresponds to the product $(\ell B_\perp)$.

$$\text{slope} = \ell B_\perp$$
$$\therefore B_\perp = \frac{\text{slope}}{\ell}$$

$$\begin{aligned}B_\perp &= \frac{\left(3.7\times10^{-4}\ \text{N/A}\right)}{(0.050\ \text{m})}\\ &= 7.4\times10^{-3}\ \text{N/A}\bullet\text{m}\\ &= 7.4\times10^{-3}\ \text{T}\end{aligned}$$

f. If there was a larger current passing through the solenoid, the magnetic field inside the solenoid would be greater. Therefore, a greater force would be exerted on the end of the loop. This would mean that the mass of the string would need to be greater to provide a larger force of gravity to balance the increased magnetic force.

g. Other relationships that could be studied using a current balance are the force on the end of the loop versus its length, and the force on the end of the loop versus the current in the solenoid.

5. The three factors which affect the magnitude of the magnetic force for a charged particle travelling through a magnetic field are the speed (v) of the charge, the magnitude of the charge (q), and the strength of the external magnetic field $(B_\perp)$.

6.
$$\begin{aligned}F_m &= I\ell B_\perp\\ &= (32.0\ \text{A})(250\ \text{m})\left(4.8\times10^{-5}\ \text{T}\right)\\ &= 3.84\times10^{-1}\ \text{N}\\ &= 3.8\times10^{-1}\ \text{N}\end{aligned}$$

7. First determine the magnetic field strength.

$$\begin{aligned}F_m &= qvB_\perp\\ 2.76\times10^{-15}\ \text{N} &= \left(1.60\times10^{-19}\ \text{C}\right)\left(2.40\times10^{6}\ \text{m/s}\right)(B_\perp)\\ B_\perp &= 7.19\times10^{-3}\ \text{Ns/Cm}\\ &= 7.19\times10^{-3}\ \text{T}\end{aligned}$$

Now calculate the force on the alpha particle.

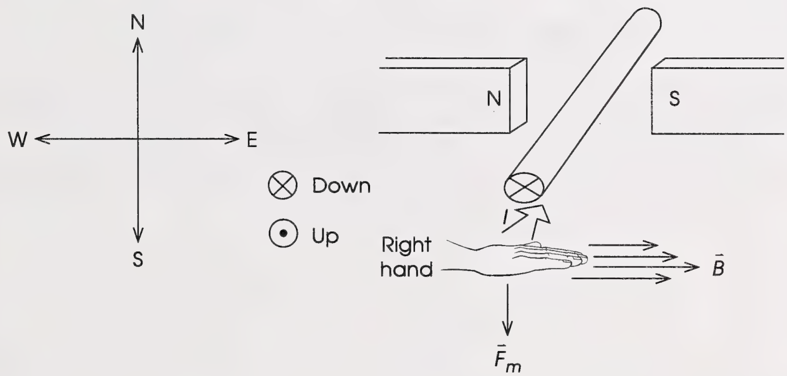
$$\begin{aligned} F_m &= qvB_{\perp} \\ &= \left(3.20\times10^{-19}\ \text{C}\right)\left(2.40\times10^{6}\ \text{m/s}\right)\left(7.19\times10^{-3}\ \text{T}\right) \\ &= 5.52\times10^{-15}\ \text{N} \end{aligned}$$

Note that this question can also be correctly answered by reasoning that since the charge doubles, the force should double, given that the speed and magnetic field are both constant.

8. To determine the magnitude of the force, use the equation $F_m = I\ell B_{\perp}$.

$$\begin{aligned} F_m &= I\ell B_{\perp} \\ &= (1.2\ \text{A})(0.45\ \text{m})\left(7.2\times10^{-3}\ \text{T}\right) \\ &= 3.9\times10^{-3}\ \text{N} \end{aligned}$$

To determine the direction of the force, use the hand rule.



The direction of the magnetic force is downwards along a line that is parallel to the plane of the page, or south. $\vec{F}_m = 3.9\times10^{-3}$ N, downwards along a line parallel to the plane of the page, or $\vec{F}_m = 3.9\times10^{-3}$ N, south.

9. Determine the current in the wire.

$$q = It$$

$$I = \frac{q}{t}$$

Place the current equation into the magnetic force equation.

$$\begin{aligned} F_m &= I\ell B_{\perp} \\ F_m &= \frac{q}{t}\ell B_{\perp} \\ \ell &= \frac{F_m t}{qB_{\perp}} \\ &= \frac{\left(7.2\times10^{-3}\ \text{N}\right)(180\ \text{s})}{(3.6\ \text{C})\left(9.0\times10^{-2}\ \text{T}\right)} \\ &= 4.0\ \text{m} \end{aligned}$$

10. $F_m = qvB_\perp$

$$q = \frac{F_m}{vB_\perp}$$

$$q = \frac{9.2\times10^{-14}\ \text{N}}{\left(2.40\times10^{6}\ \text{m/s}\right)\left(4.8\times10^{-2}\ \text{T}\right)}$$

$$= 7.99\times10^{-19}\ \text{C}$$

$$= 8.0\times10^{-19}\ \text{C}$$

Set up the ratio to determine number of elementary charges.

$$\frac{1\ \text{elementary charge}}{1.60\times10^{-19}\ \text{C}} = \frac{x}{8.0\times10^{-19}\ \text{C}}$$

$$x = \frac{\left(1\ \text{elementary charge}\right)\left(8.0\times10^{-19}\ \text{C}\right)}{\left(1.60\times10^{-19}\ \text{C}\right)}$$

$$= 5\ \text{elementary charges}$$

Students should express their answer as a whole number since the particle has a net deficit or surplus of 5 elementary charges.

11. Equate F_c and F_m.

$$F_c = F_m$$

$$\frac{mv^2}{r} = qvB_\perp$$

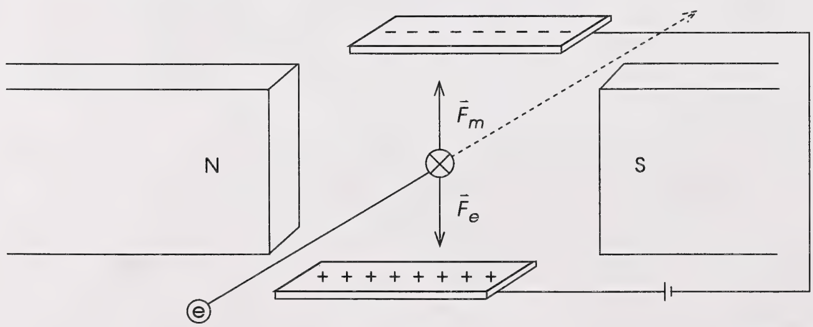
$$\frac{mv}{r} = qB_\perp$$

$$r = \frac{mv}{B_\perp q}$$

$$= \frac{\left(6.65\times10^{-27}\ \text{kg}\right)\left(5.0\times10^{6}\ \text{m/s}\right)}{\left(6.4\times10^{-2}\ \text{T}\right)\left(3.20\times10^{-19}\ \text{C}\right)}$$

$$= 1.6\ \text{m}$$

12. a. $\vec{F}_e$ is directed downwards along a line that is parallel to the plane of the page because unlike charges attract. $\vec{F}_m$ is directed upwards along a line that is parallel to the plane of the page. This is determined by the left-hand rule.



b. The electron travels undeflected, the electric force is balanced by the magnetic force. The solution begins by equating the magnitudes of these forces.

$V = 2000 \text{ V}$

$d = 0.080 \text{ m}$

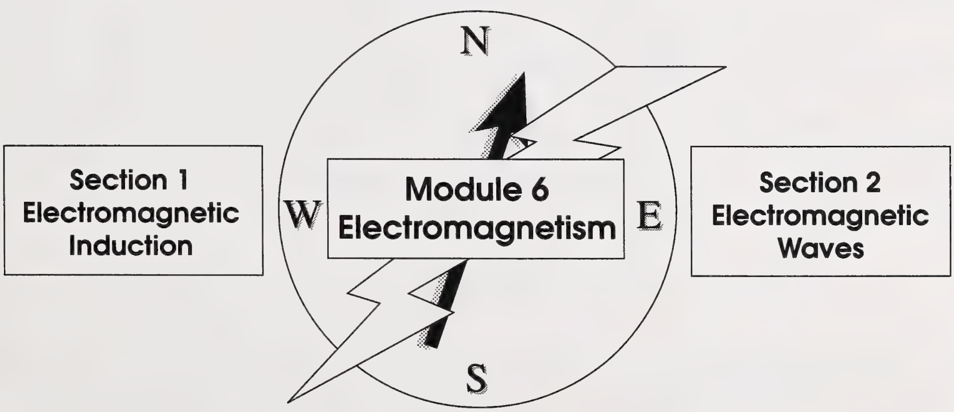
$B_{\perp} = 0.0028 \text{ T}$

$$
\begin{aligned}
F_e &= F_m \\
|\vec{E}|q &= qvB_{\perp} \\
\vec{E} &= vB_{\perp} \\
\frac{V}{d} &= vB_{\perp} \\
v &= \frac{V}{B_{\perp}d} \\
&= \frac{(2000 \text{ V})}{(0.0028 \text{ T})(0.080 \text{ m})} \\
&= 8.93 \times 10^6 \text{ m/s} \\
&= 8.9 \times 10^6 \text{ m/s}
\end{aligned}
$$

Module 6: Electromagnetism

Overview

This module ties together ideas from the previous five modules, especially the concepts of electricity and magnetism, by a study of electromagnetic induction. The study of the way in which a transformer operates serves to link the concepts of conservation of energy to electromagnetic phenomena. The concluding section, Electromagnetic Waves, provides a link to concepts covered in Physics 20 on the nature of waves and light. In general the module attempts to introduce the topics in a context that is familiar to most students and sets the stage for further studies of electromagnetic principles and phenomena.



Materials and Equipment

The following is a list of the materials and equipment necessary for an individual to complete the investigation and activities in Module 6. If more than one individual is involved, the amount of equipment will need to be adjusted.

Section 1: Activity 3

Investigation: The Lenz's Law Swing

- 2 m of thread
- a bar magnet or cylindrical magnet
- 30 cm of masking tape
- a $1\frac{1}{2}$-inch copper coupling (available where plumbing supplies are found)

Section 1: Activity 4

Investigation: Induction and the Transformer

- both a 400- and 800-turn solenoid (from module 5)
- four wire leads with alligator clips at both ends
- a multimeter capable of measuring microamperes, or a microammeter
- a bar magnet or cylindrical magnet
- a variable power supply (3-V and 9-V output)
- the large steel bolt $\left(\frac{1}{2}\text{- inch diameter, 4 inches long}\right)$
- 30-Ω power resistor rated at 5 W

Section 2: Activity 1

Investigation: Induction of Electric and Magnetic Fields

- the 800-turn solenoid constructed in Module 5
- a steel bolt
- the variable power supply capable of 12 -V DC output
- a radio, preferably portable
- 30-Ω power resistor rated at 5 W

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 6. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Electromagnetism: Electromagnetic Induction,* TV Ontario (Available through ACCESS Network)
– *Wave Particle Duality: The Electromagnetic Model*, TV Ontario (Available through ACCESS Network)

Both of these ideas provide a concise reinforcement of the main ideas. Another video that is available from the Canadian Cancer Society is called *Your Skin and the Sun.* This thirteen-minute video has a concise explanation of the different types of skin cancers and provides students with valuable insights into the whole idea of suntanning.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	60%
Section 2 Assignment	40%
TOTAL	100%

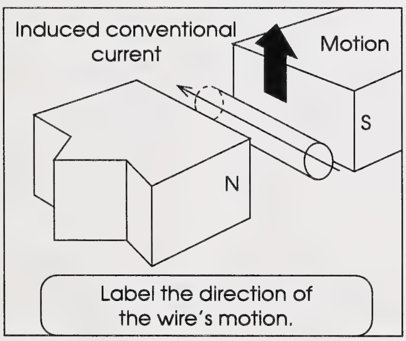
Section 1: Electromagnetic Induction

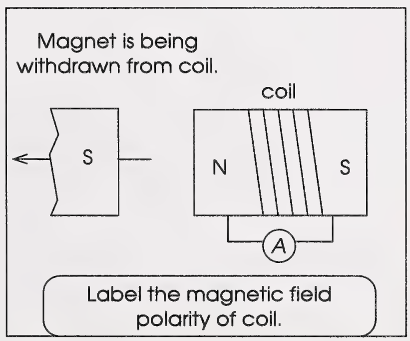
If there is one topic that students in Physics 30 universally find difficult, this is it. Although the basic learning that students are responsible for concerns electromagnetic induction, Lenz's law, and transformers, much more has been added to the section to act as support material to give the students the linking explanations and practice that they seem to need.

The ideas are heavily dependent upon the hand rules that the students learned in the previous module. It's a good idea to have students practise these hand rules as much as possible, especially when they are working with the materials in lab investigations and demonstrations.

Section 1: Assignment Answer Key (60 marks)

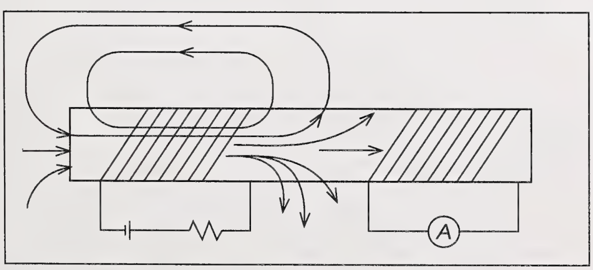
1. a.





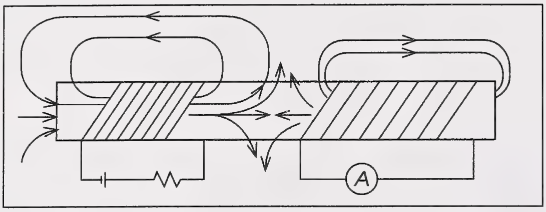
b. Use the right-hand rule to solve for the direction of the wire's motion. Your fingers point to the south pole, your palm faces the direction of induced current, and your thumb will point to the direction of the wire's motion. For the coil use Lenz's law to solve for the magnetic polarity. If a south pole is being pulled away from the coil, a magnetic north pole will be induced to oppose the motion.

2. a.



If the current through solenoid A is increased, the magnetic flux will increase to the right, as shown in the diagram.

b.



According to Lenz's law, the induced magnetic field will be set up to oppose the increase in flux due to solenoid A. The magnetic field in B will increase to the left, as shown in the diagram.

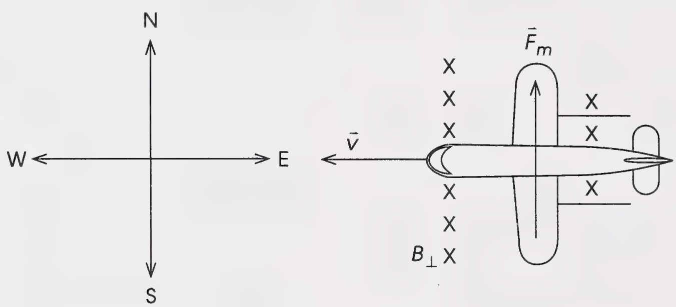
c. The right-hand rule for coils determines that the conventional current will pass from right to left through the meter.

3. a.

$B_\perp = 8.30 \times 10^{-5}$ T
$v = 350$ m/s
$\ell = 22$ m
$V = ?$

$$V = B_\perp \ell v$$
$$= \left(8.30 \times 10^{-5}\ \text{T}\right)(22\ \text{m})(350\ \text{m/s})$$
$$= 6.4 \times 10^{-1}\ \text{V}$$

b.



The left-hand rule for force shows that the negative changes will be directed towards the wing on the north side.

4. a. The positive charge is attracted to the plate on the right side, so this plate is negatively charged. It follows from this that there is an excess of electrons on the right-hand plate. These electrons must have collected on this plate because they flowed from the left hand plate and the wire. Using this line of thinking, the electrons must be flowing from back to front, or counterclockwise, in the wire between the magnets.

b. The left-hand rule for forces determines that if the electrons are forced from back to front, the magnetic field lines must be directed down. This means that the top pole of the magnet is the north pole and the bottom pole of the magnet is the south pole.

5. a.

$N_s = 800$
$P = 1.00 \times 10^4$ W
$N_p = ?$

$V_p = 40.0$ V
$I_s = 3.125$ A

Step 1: Find the secondary voltage.

$$P = I_s V_s$$
$$V_s = \frac{P}{I_s}$$
$$= \frac{1.00 \times 10^4\ \text{W}}{3.125\ \text{A}}$$
$$= 3200\ \text{V}$$

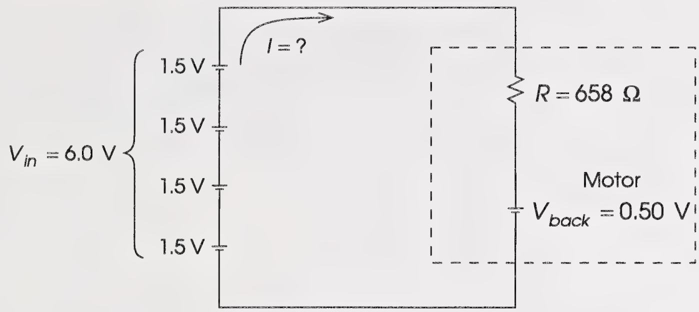
Step 2: Calculate the number of turns.

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$$N_p = \frac{V_p}{V_s} N_s$$
$$= \frac{(40.0\ \text{V})(800)}{3200\ \text{V}}$$
$$= 10$$

Note that the number of turns should be a whole number.

b. Since there are more turns on the secondary coil than on the primary coil, this is a step-up transformer. This is confirmed by the fact that the voltage in the primary coil is stepped up to 3200 V in the secondary coil.

6. a.



b. At this instant the motor is not yet turning, so the back-EMF is zero. The problem can be solved using Ohm's law.

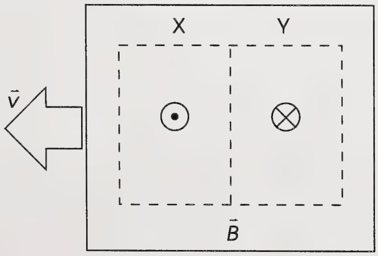
$V_{in} = 6.0\ \text{V}$
$R = 658\ \Omega$
$I = ?$

$$\begin{aligned} V_{in} &= IR \\ I &= \frac{V_{in}}{R} \\ &= \frac{6.0\ \text{V}}{658\ \Omega} \\ &= 9.1 \times 10^{-3}\ \text{A} \end{aligned}$$

c. When the car is moving across the floor, the back-EMF needs to be considered. Kirchoff's loop rule is the best way to handle this.

$$\begin{aligned} V_{in} - V_{resistance} - V_{back} &= 0 \\ V_{in} - IR - V_{back} &= 0 \\ IR &= V_{in} - V_{back} \\ I &= \frac{V_{in} - V_{back}}{R} \\ &= \frac{(6.0\ \text{V}) - (0.50\ \text{V})}{658\ \Omega} \\ &= 8.4 \times 10^{-3}\ \text{A} \end{aligned}$$

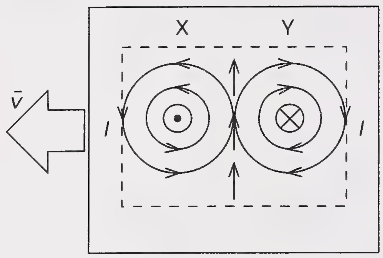
7. a.



In region X the magnetic flux decreased during the time interval from $t = 0$ s to $t = 1$ ms. According to Lenz's law, an induced magnetic field will be created in region X to oppose this change by maintaining the initial magnetic field.

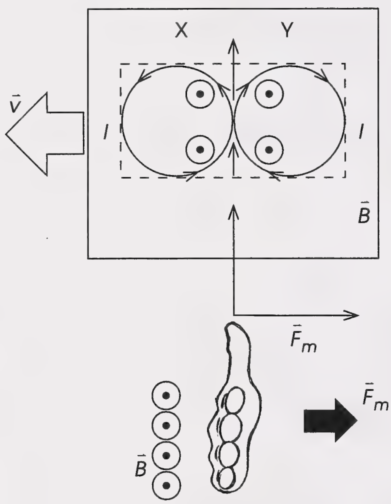
In region Y the magnetic field increased from zero during the time interval from $t = 0$ s to $t = 1$ ms. According to Lenz's law, an induced magnetic field will be created in region Y to oppose this change by creating magnetic field lines in the opposite direction.

b.



The right-hand rule for conductors shows that currents will be induced in each region as shown in the diagram. The currents will reinforce each other at the boundary between regions X and Y.

c.



The right-hand rule for force shows that the eddy currents will experience a force opposite to the direction of the velocity of the conductor.

Note that the magnetic field does not extend to the outside edges of regions X and Y. It follows that in the region of the magnetic field, the net current is directed upwards.

d. The thermal energy created by the eddy currents comes from the kinetic energy of the conductor moving through the magnetic field.

e. When the wheels move at a maximum speed, the magnetic flux is changing rapidly, which means that the induced eddy currents are large and therefore the opposing force is large. Similarly, low wheel speeds mean that the rate of changing magnetic flux is lower, and therefore the magnitude of the induced currents is lower and so is the opposing force.

Section 2: Electromagnetic Waves

This section is based on the basic ideas from the Section 1, but this section is one that students usually find easier and more interesting. The focus of the section is the comparing and contrasting of the constituents of the electromagnetic spectrum, so the topics are presented in a descriptive format that focuses on applications. Many of the topics introduced here will be explored in greater detail in future modules.

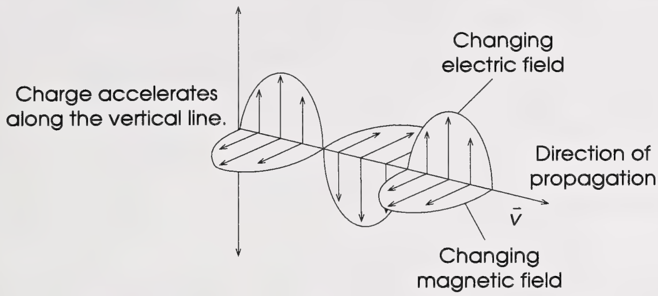
Section 2: Assignment Answer Key (40 marks)

1. a. The source of all electromagnetic radiation is an accelerating charged particle. If the particle is not charged, it cannot create the changing magnetic and electric fields.

   b. Electromagnetic radiation having a frequency of 1.0×10^{15} Hz would be classified as ultraviolet radiation. Since visible light has a frequency of about 10^{14} Hz anything higher than this must be toward the high-energy end of the spectrum.

c. When an electromagnetic wave passes from one material into another with a higher index of refraction, its frequency will remain the same. Frequency depends on the source of the wave and not on the medium.

2.



3. There are three reasons why the radio antenna is unlikely to have caused the sparks in the metal fence. Students should mention at least two of them.

- Radio waves are basically a low-energy electromagnetic wave. It is unlikely that they would carry sufficient energy to cause electrocution.
- The wavelength emitted by the tower is 450 m. For reception to occur, the wire fence must need to be about 225 m long (half the wavelength). The fence is too short to act as a receiver.
- The electric portion of the EM wave is transmitted vertically, but the fence is horizontal and so it would not be a good receiver.

$$c = f\lambda$$
$$\lambda = \frac{c}{f}$$
$$= \frac{3.00 \times 10^8 \text{ m/s}}{6.67 \times 10^5 \text{ /s}}$$
$$= 450 \text{ m}$$

4. Diffraction is a phenomena that depends on the relative size of the wavelength and the objects. If the wavelength is the same size or larger than the objects, diffraction will be observable. Light waves are millions of times smaller than objects like buildings, so it is unlikely that any diffraction will occur. However, light waves will diffract through very narrow openings.

5. DNA is the most important material in a cell. This material is most vulnerable to ionizing radiation. When cells are dividing, the DNA must replicate. It follows that cells that are dividing frequently are the most vulnerable to ionizing radiation. Cells that are in this category include the cells of the skin, bone marrow, and intestinal lining.

6. a. As shown by the location of city C, in the afternoon the sun's rays do not have to cross as large a thickness of the atmosphere as they do in the early evening, as shown by the location of city B. This means that more ultraviolet rays will be able to penetrate to ground level at city C.

b. People living at high altitudes have less atmosphere above them to absorb ultraviolet rays. Therefore, more ultraviolet rays can penetrate to ground level at higher altitudes.

c. The ultraviolet rays from the sun are forced to pass through the upper boundary of the ionosphere above city B. Many of the ultraviolet rays that could have reached the lower part of the ionosphere above city B have already been absorbed. This means that the upper boundary of the ionosphere is becoming highly ionized.

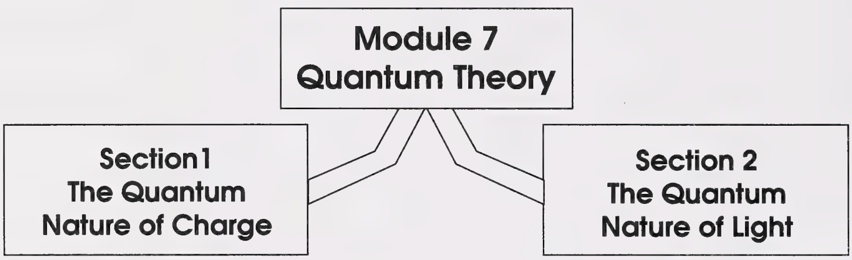
d. As explained in the answer to part c, the upper parts of the ionosphere become highly ionized during and just after sunset. This means that the layer that actively reflects AM radio waves is now improved in its ability to reflect and it is higher so it can reflect further. Since the effects of this intense ionization remain for a few hours after sunset, city A will have the highest reflective ceiling and the best reception. City B will have the second best and city C will have the worst.

e. FM radio waves do not reflect off the ionosphere, so their broadcast reception is limited by the curve of the earth and is unaffected by changes in the ionosphere.

Module 7: Quantum Theory

Overview

This module introduces students to the basic ideas from early quantum theory. The historical development of the discovery of the electron leads students to the idea that charge is quantized in Section 1. Section 2 deals with the quantization of light energy through an examination of the development of the photon model for light. The module ends with the concept of wave-particle duality being applied to both electrons and photons.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 7. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Investigation: Simulating Millikan's Data Analysis

Part A

- a sensitive balance (preferably electronic)
- at least fifty identical ball bearings or fifty identical coins (pennies)
- a small container to hold the ball bearings or coins

Part B

- No materials are needed for this part as sample data is provided.

Section 2: Activity 2

Investigation: Exploring the Properties of LEDs

- three LEDs: one red, one green, and one amber
- a variable low-voltage DC power supply with a range of approximately 5 V to 20 V
- a 510-Ω resistor rated at 0.5-W power handling (The stripes on this resistor will be green, brown, brown, gold.)

- four wire connectors with alligator clips at each end
- a multimeter capable of measuring 0 mA to 30 mA or an ammeter with this range

Investigation: Calculating Planck's Constant

- The materials for this investigation are nearly identical to the previous one. The only change is that the multimeter must also be able to measure 0 V to 20 V, DC, or you will need a voltmeter with this range.

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 7. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Structure of the Atom (The Earliest Models, Smaller than the Smallest)*
– *Wave Particle Duality (The Quantum Idea, Photons, Matter Waves)*

These videos consist of six ten-minute programs originally produced by TV Ontario. Only those programs used in this module are listed here. The videocassettes are available through ACCESS Network.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	50%
Section 2 Assignment	50%
TOTAL	100%

Section 1: The Quantum Nature of Charge

This section helps students to trace the historical chain of events that eventually led to the discovery of the electron. The section provides many opportunities for students to recall, apply, and reinterpret key concepts from earlier modules. This makes this section an excellent opportunity for students to practise linking key ideas in problem solving – a skill which will likely be stressed on the diploma exam.

The section ends with the idea that charge is quantized. As the title of the module suggests, this is the main theme of both Sections 1 and 2. The idea that the subatomic world has a quantum nature will be reinforced in Section 2 and especially in Module 9.

Section 1: Assignment Answer Key (50 marks)

1. Textbook question 13:

$$q = 8.0\times10^{-19}\ \text{C}$$
$$d = 8.0\ \text{mm} = 8.0\times10^{-3}\ \text{m}$$
$$V = 1200\ \text{V}$$
$$F_g = mg = ?$$

$$\begin{aligned}
\vec{F}_{net} &= \vec{F}_e + \vec{F}_g = 0 \\
\left|\vec{F}_e\right| - \left|\vec{F}_g\right| &= 0 \\
\left|\vec{F}_e\right| &= \left|\vec{F}_g\right| \\
\left|\vec{E}\right|q &= \left|\vec{F}_g\right| \\
\left|\vec{F}_g\right| &= \frac{V}{d}q \\
&= \frac{(1200\ \text{V})}{\left(8.0\times10^{-3}\ \text{m}\right)}\left(8.0\times10^{-19}\ \text{C}\right) \\
&= 1.2\times10^{-13}\ \text{N}
\end{aligned}$$

2. $q = 1.60\times10^{-19}\ \text{C}$

$$v = 1.9\times10^{4}\ \text{m/s}$$
$$B_\perp = 1.0\times10^{-3}\ \text{T}$$
$$r = 0.40\ \text{m}$$

$$\begin{aligned}
F_c &= F_m \\
\frac{mv^{\cancel{2}}}{r} &= B_\perp \cancel{v} q \\
m &= \frac{B_\perp qr}{v} \\
&= \frac{\left(1.0\times10^{-3}\ \text{T}\right)\left(1.60\times10^{-19}\ \text{C}\right)(0.40\ \text{m})}{1.9\times10^{4}\ \text{m/s}} \\
&= 3.4\times10^{-27}\ \text{kg}
\end{aligned}$$

3. $B_\perp = 0.040\ \text{T}$

$$r = 0.20\ \text{m}$$
$$V = 200\ \text{J/C}$$
$$d = 10\ \text{cm}$$
$$\frac{q}{m} = ?$$

$$\begin{aligned}
F_e &= F_m \\
\left|\vec{E}\right|\cancel{q} &= B_\perp v\cancel{q} \\
v &= \frac{\left|\vec{E}\right|}{B_\perp}
\end{aligned}$$

$$\begin{aligned}
F_m &= F_c \\
qvB_\perp &= \frac{mv^2}{r} \\
\frac{q}{m} &= \frac{v}{B_\perp r} \\
&= \frac{\left|\vec{E}\right|}{B_\perp{}^2 r} \\
&= \frac{V}{dB_\perp{}^2 r} \\
&= \frac{200\ \text{J/C}}{(0.10\ \text{m})(0.040\ \text{T})^2\,(0.20\ \text{m})} \\
&= 6.3\times10^{6}\ \text{C/kg}
\end{aligned}$$

4. The undeflected path of the electrons indicates that the electric force is completely balanced by the magnetic force. Since the electric force on the electrons is up (towards the positive plate), the magnetic force must be down. Using the left-hand rule for force, if the velocity of the electrons is to the right and the direction of the magnetic force is down, the direction of the magnetic field lines must be into the page. Using the right-hand rule for coils, if the magnetic field lines are directed into the page, the conventional current flowing around the coil must be in a clockwise direction.

5. The charges are already arranged in order from smallest to largest. The technique here is to find the **difference** between adjacent values and then look for a pattern in those values.

Values $(\times 10^{-19}\ \text{C})$	Differences $(\times 10^{-19}\ \text{C})$	Patterns in Multiple Value $(\times 10^{-19}\ \text{C})$
6.563		
	1.641	
8.204		
	3.296 →	$3.296 \div 2 = 1.648 = 1.65$
11.50		
	1.63	
13.13		
	3.35 →	$3.35 \div 2 = 1.675 = 1.68$
16.48		
	1.60	
18.08		
	1.63	
19.71		
	3.18 →	$3.18 \div 2 = 1.59$
22.89		
	3.24 →	$3.24 \div 2 = 1.62$
26.13		

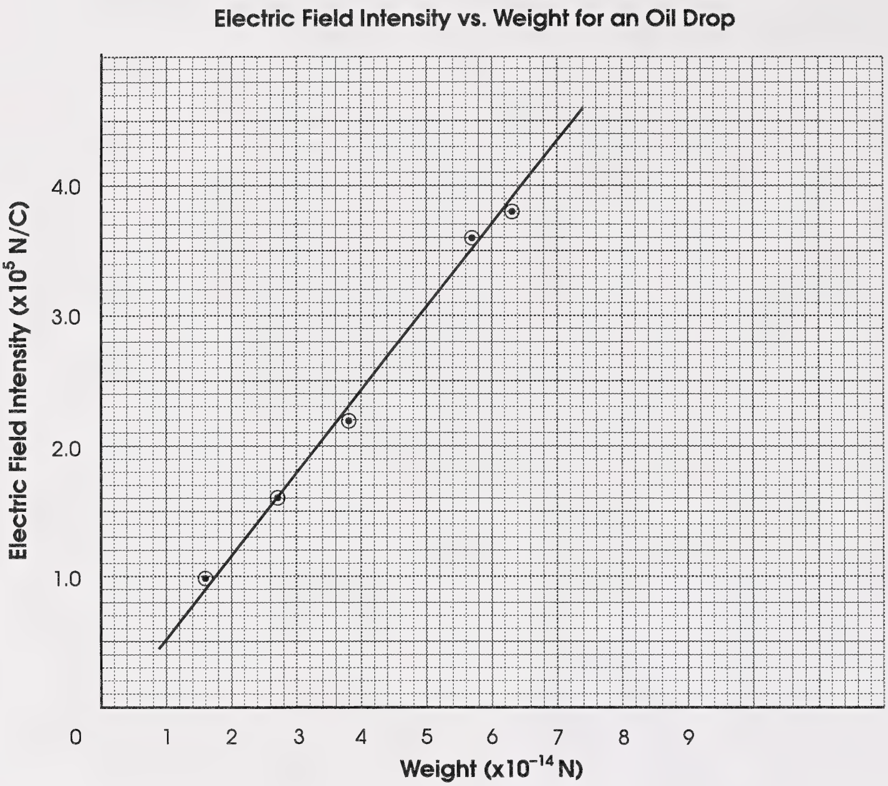
The smallest difference is 1.60×10^{-19} C, with some of the other values very close to this one. Four of the values have values that are nearly double the smallest value. If these values are divided by 2, the same value of approximately 1.60×10^{-19} C begins to appear.

Using the eight 1.60×10^{-19} C values (from either the differences or the multiples), the best value for the elementary charge can be determined.

$$
\begin{aligned}
q &= \frac{\sum \Delta q}{n} \\
&= \frac{\left(13.034 \times 10^{-19}\ \text{C}\right)}{8} \\
&= 1.629\,25 \times 10^{-19}\ \text{C} \\
&= 1.63 \times 10^{-19}\ \text{C}
\end{aligned}
$$

Note that students could use a different averaging procedure to arrive at the same answer of 1.63×10^{-19} C. The alternative method is to sum up all of the differences and then divide by 12, since this is the total number of charges that account for these differences.

6. a.



b.

$F_g = F_e$ This is the condition to have a suspended drop.

$mg = q\left|\vec{E}\right|$

$\left|\vec{E}\right| = \dfrac{mg}{q}$

$\left|\vec{E}\right| = \left(\dfrac{1}{q}\right)\underbrace{mg}$

By inspection $y = \quad m \quad x + b$

As these equations indicate, the slope of this graph should equal the inverse of the elementary charge.

$$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{\left(3.7\times10^{5}\ \text{N/C} - 0.9\times10^{5}\ \text{N/C}\right)}{\left(6.0\times10^{-14}\ \text{N} - 1.6\times10^{-14}\ \text{N}\right)}\\ &= \frac{2.8\times10^{5}\ \text{N/C}}{4.4\times10^{-14}\ \text{N}}\\ &= 6.36\times10^{18}\ \frac{1}{\text{C}}\end{aligned}$$

$$\begin{aligned}\text{slope} &= \frac{1}{q}\\ \therefore q &= \frac{1}{\text{slope}}\\ &= \frac{1}{\left(6.36\times10^{18}\ \frac{1}{\text{C}}\right)}\\ &= 1.57\times10^{-19}\ \text{C}\\ &= 1.6\times10^{-19}\ \text{C}\end{aligned}$$

Section 2: The Quantum Nature of Light

This section extends the quantum ideas from Section 1 to the study of light. There are wonderful opportunities here for students to build on concepts from Physics 20 as the wave and particle models for light are combined with quantum ideas to form the photon model of light.

It is important that students realize that the photon model is more abstract than the others. This model does not lend itself to comparison to familiar, large-scale objects because of the implications of wave-particle duality. Students should be led to the idea that photons are so unlike large-scale objects that the words *wave* and *particle* are inadequate by themselves to describe how photons behave. By the time the section ends, the wave-particle duality is extended to electrons.

Section 2: Assignment Answer Key (50 marks)

1. $v = 1.20 \times 10^{6}$ m/s
   $m = 9.11 \times 10^{-31}$ kg
   $f_{max} = ?$

$$\sum E_{in} = \sum E_{out}$$
$$E_k = E_{x\text{-}ray}$$
$$\frac{1}{2}mv^2 = hf_{max}$$
$$f_{max} = \frac{\frac{1}{2}mv^2}{h}$$
$$= \frac{\frac{1}{2}\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(1.20 \times 10^{6}\ \text{m/s}\right)^2}{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}$$
$$= 9.89 \times 10^{14}\ \text{Hz}$$

2. $E = 6.0$ MeV

$$= 6.0 \times 10^{6}\ \text{eV}\left[\frac{1.60 \times 10^{-19}\ \text{J}}{1\ \text{eV}}\right]$$
$$= 9.6 \times 10^{-13}\ \text{J}$$

   $p = ?$

$$p = \frac{E}{c}$$
$$= \frac{9.6 \times 10^{-13}\ \text{J}}{3.00 \times 10^{8}\ \text{m/s}}$$
$$= 3.2 \times 10^{-21}\ \text{kg}\bullet\text{m/s}$$

   $p = 3.2 \times 10^{-21}$ kg•m/s
   $m = 1.67 \times 10^{-27}$ kg
   $v = ?$

$$p = mv$$
$$v = \frac{p}{m}$$
$$= \frac{3.2 \times 10^{-21}\ \text{kg}\bullet\text{m/s}}{1.67 \times 10^{-27}\ \text{kg}}$$
$$= 1.9 \times 10^{6}\ \text{m/s}$$

3. $E_k = 3.00 \times 10^{-18}$ J

$m = 9.11 \times 10^{-31}$ kg

$v = ?$

$\lambda = ?$

$$E_k = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\frac{2(3.00 \times 10^{-18}\ \text{J})}{9.11 \times 10^{-31}\ \text{kg}}}$$

$$= 2.566 \times 10^{6}\ \text{m/s}$$

$$= 2.57 \times 10^{6}\ \text{m/s}$$

$$\lambda = \frac{h}{mv}$$

$$= \frac{6.63 \times 10^{-34}\ \text{J} \bullet \text{s}}{(9.11 \times 10^{-31}\ \text{kg})(2.566 \times 10^{6}\ \text{m/s})}$$

$$= 2.836 \times 10^{-10}\ \text{m}$$

$$= 2.84 \times 10^{-10}\ \text{m}$$

4. $W = 4.45\ \text{eV}\left[\frac{1.60 \times 10^{-19}\ \text{J}}{1\ \text{eV}}\right] = 7.12 \times 10^{-19}\ \text{J}$

$\lambda = 1.25 \times 10^{-7}$ m

$V_{stop} = ?$

$q = 1.60 \times 10^{-19}$ C

$$hf = E_{max} + W$$

$$E_{k_{max}} = h\frac{c}{\lambda} - W$$

$$qV_{stop} = h\frac{c}{\lambda} - W$$

$$V_{stop} = \frac{h\frac{c}{\lambda} - W}{q}$$

$$= \frac{(6.63 \times 10^{-34}\ \text{J} \bullet \text{s})\left(\frac{3.00 \times 10^{8}\ \text{m/s}}{1.25 \times 10^{-7}\ \text{m}}\right) - (7.12 \times 10^{-19}\ \text{J})}{1.60 \times 10^{-19}\ \text{C}}$$

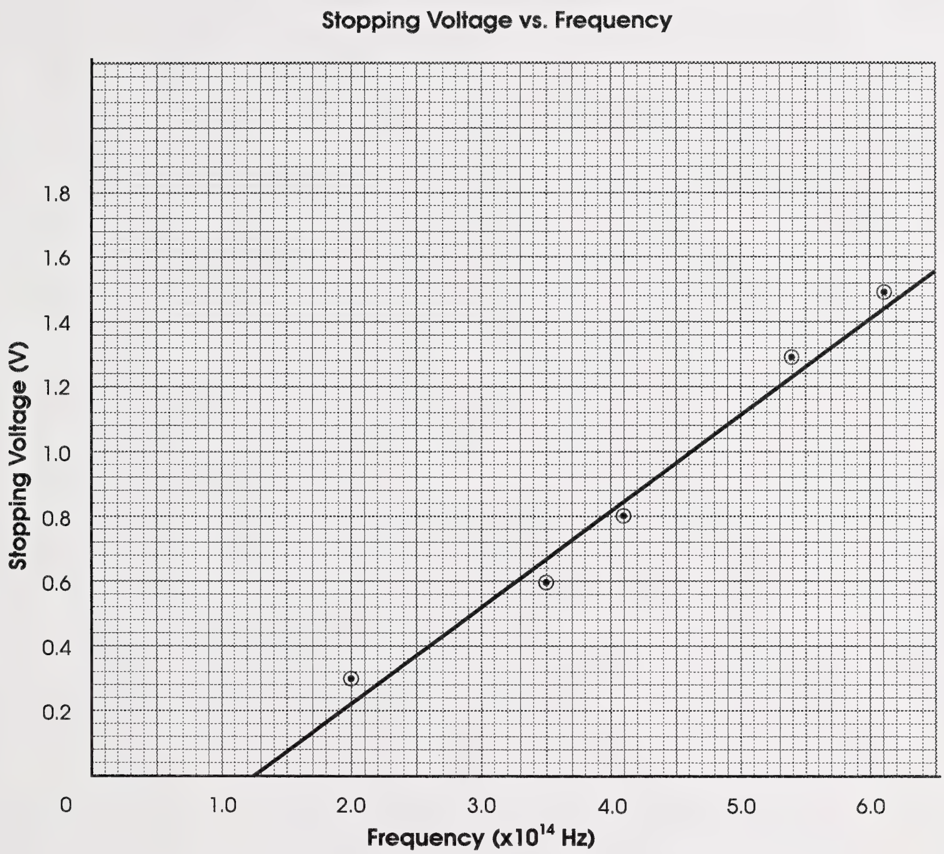
$$= 5.495\ \text{V}$$

$$= 5.50\ \text{V}$$

5. Photons of ultraviolet light have a higher frequency and therefore a higher energy than the photons of infrared radiation. This higher energy is capable of ionizing atoms. This means that the infrared photons do not have enough energy to cause this kind of damage.

6. Red light photons have the lowest frequency of all visible light and therefore the lowest energy. If the photographic film is not sensitive to this light, the photons do not have enough energy to cause the chemical changes associated with developing the film. This film could be developed with the red safelight on because no further developing will occur due to these photons.

7. a.



b.

$$hf = E_{k_{max}} + W$$

$$E_{k_{max}} = hf - W$$

$$qV_{stop} = hf - hf_o$$

$$V_{stop} = \left(\frac{h}{q}\right)f - \underbrace{\frac{hf_o}{q}}$$

By inspection

$$y = m\ x + b$$

As the equations indicate, the slope of this graph should be equal to Planck's constant divided by the elementary charge.

- Find the slope.

$$\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}} \\
&= \frac{(1.44\ \text{V} - 0.08\ \text{V})}{\left(6.1\times10^{14}\ \text{Hz} - 1.5\times10^{14}\ \text{Hz}\right)} \\
&= \frac{1.36\ \text{V}}{4.6\times10^{14}\ \text{Hz}} \\
&= 2.9565\times10^{-15}\ \cancel{\text{V}}\bullet\text{s}\left[\frac{\text{J/C}}{\cancel{\text{V}}}\right] \\
&= 2.9565\times10^{-15}\ \frac{\text{J}\bullet\text{s}}{\text{C}} \\
&= 2.96\times10^{-15}\ \frac{\text{J}\bullet\text{s}}{\text{C}}
\end{aligned}$$

- Calculate Planck's constant.

$$\begin{aligned}
\text{slope} &= \frac{h}{q} \\
h &= (\text{slope})q \\
&= \left(2.9565\times10^{-15}\ \frac{\text{J}\bullet\text{s}}{\cancel{\text{C}}}\right)\left(1.60\times10^{-19}\ \cancel{\text{C}}\right) \\
&= 4.73\times10^{-34}\ \text{J}\bullet\text{s}
\end{aligned}$$

c.

$$\begin{aligned}
hf &= E_{k_{\text{max}}} + W \\
hf &= W \\
hf &= hf_o \\
f &= f_o \\
f_o &= x\text{-intercept} \\
&= 1.25\times10^{14}\ \text{Hz}
\end{aligned}$$

When the frequency is the threshold frequency, $E_{k_{max}} = 0$. Therefore use the x-intercept to determine the threshold frequency.

8. a.

$$\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}} \\
&= \frac{(18.0\ \text{V} - 3.1\ \text{V})}{\left(28.4\times10^{-3}\ \text{A} - 0\ \text{A}\right)} \\
&= 524.6\ \Omega \\
&= 525\ \Omega
\end{aligned}$$

b. $$\sum E_{before} = \sum E_{after}$$

$$E_{power\ supply} = E_{thermal} + E_{light}$$

$$qV_{power\ supply} = q(IR) + \frac{hc}{\lambda}$$

$$V_{power\ supply} = IR + \frac{hc}{q\lambda}$$

c. $$V_{power\ supply} = RI + \frac{hc}{q\lambda}$$

By inspection

$$y \quad = \quad mx + \quad b$$

As shown, the experimental value for Planck's constant can be found by equating $\frac{hc}{q\lambda}$ to the y-intercept.

$b = 3.1\ \text{V}$

$\lambda = 4.3 \times 10^{-7}\ \text{m}$

$q = 1.60 \times 10^{-19}\ \text{C}$

$c = 3.00 \times 10^{8}\ \text{m/s}$

$h = ?$

$$b = \frac{hc}{q\lambda}$$

$$h = \frac{bq\lambda}{c}$$

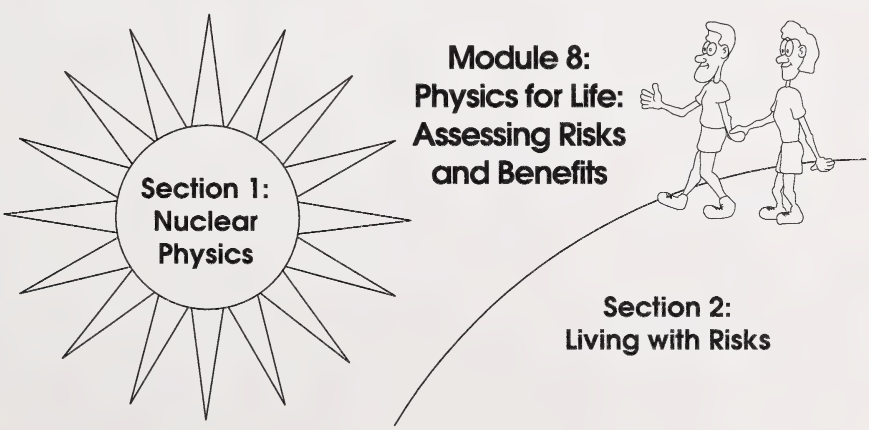
$$h = \frac{(3.1\ \text{V})\left(1.60 \times 10^{-19}\ \text{C}\right)\left(4.3 \times 10^{-7}\ \text{m}\right)}{\left(3.00 \times 10^{8}\ \text{m/s}\right)}$$

$$= 7.1 \times 10^{-34}\ \text{J} \bullet \text{s}$$

Module 8: Physics for Life: Assessing Risks and Benefits

Overview

This module introduces students to the basic ideas of nuclear physics and provides students with some insights about why nuclear applications can be so controversial. The whole module is presented in a survey fashion to acquaint students with only the main ideas. This is why the video component is such a good teaching resource here, since the curriculum does not imply a great depth of coverage. Students should be presented with a learning environment that allows them to develop their own viewpoint about the risks involved with nuclear technologies. The stress should not be so much on their particular opinions, but rather on how well they can justify their particular points of view.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 8. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Students will do **one** of these investigations.

Investigation: A Group of Students Simulate Half-life

- twenty pennies
- graph paper

Investigation: One Student Simulates Half-life

- 100 pennies
- a shoe box
- graph paper

Additional Resources

- The same resources listed for Module 1 can provide additional support and information for teaching Module 8. Please refer to the list presented for Module 1.

- The topics of risk and risk assessment are new to most science teachers. Excellent background reading for teachers can be found in the April 17, 1987 edition of *Science*. This journal provides six articles on the issues of risk assessment. It is worth noting that the articles *Risk Assessment and Comparisons: An Introduction*, by R. Wilson and E.A.C. Crouch, and *Perception of Risk,* by Slovic, were used extensively in guiding the design of Section 2 of this module.

Possible Media

Videocassettes – *Nuclear Physics*, TV Ontario (Available through ACCESS Network). This is essential to Section 1 as there is no pathway.
– *Nova: Back to Chernobyl*, Vestron Video (Available through ACCESS Network)

These videocassettes are crucial for the instruction of this module. They motivate, enlighten, explain, and enliven the students to this whole topic in a very concise way.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on two assignments:

Section 1 Assignment	60%
Section 2 Assignment	40%
TOTAL	100%

Section 1: Nuclear Physics

This section introduces students to the main ideas behind nuclear power. It would be a mistake to make this study either overly detailed or too quantitative since the intention is simply to acquaint students with this topic.

Section 1: Assignment Answer Key (60 marks)

1. $^{64}_{29}\text{Cu}$

2. $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$

3. $^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$

   Note that the decay of carbon 14 also includes the emission of an antineutrino, but this has been omitted from the solution shown in the interest of simplicity.

4. $^{34}_{15}\text{P} \rightarrow {}^{34}_{16}\text{S} + {}^{0}_{-1}\text{e} + \gamma$

5. $^{65}_{29}\text{Cu} + {}^{1}_{0}\text{n} \rightarrow {}^{65}_{28}\text{Ni} + {}^{1}_{1}\text{p}$

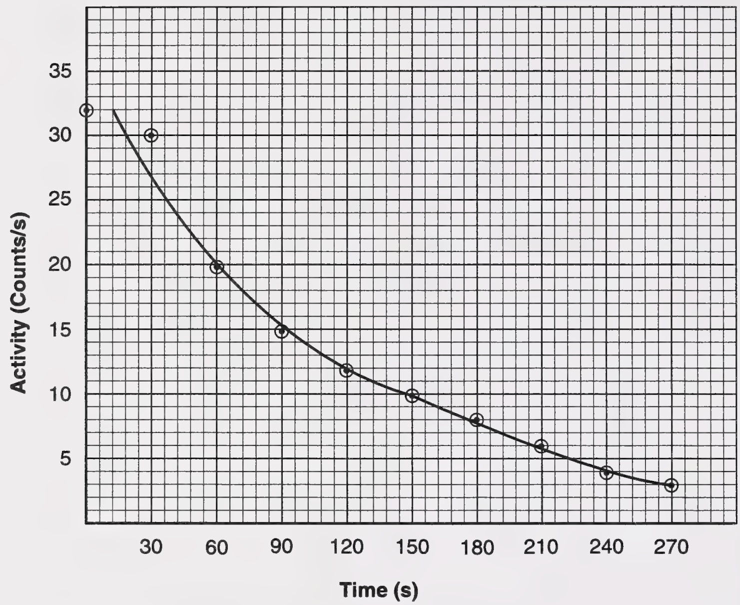
   The new isotope is nickel 65 $\left(^{65}_{28}\text{Ni} \right)$.

6. $^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{96}_{40}\text{Zr} + 3\left({}^{1}_{0}\text{n} \right) + {}^{137}_{52}\text{Te}$

   The new isotope is tellurium 137 $\left(^{137}_{52}\text{Te} \right)$.

7. a.

Activity-Time Graph for a Radioactive Sample



b. The following information was obtained from the graph.

from 32 counts/s to 16 counts/s in 72 s
from 20 counts/s to 10 counts/s in 87 s
from 10 counts/s to 5 counts/s in 75 s
from 16 counts/s to 8 counts/s in 92 s
from 12 counts/s to 6 counts/s in 87 s

The average of these half-lives is $82.6\ \text{s} = 83\ \text{s}$

The activity is one-half of its original amount after its half-life period. From the data, you could conclude that the half-life is approximately 83 s. Note that answers ranging from 75 s to 90 s could be considered valid because this is an estimation based on the curve drawn for the graph.

8. Textbook question 13:

In six years, three half-lives would have occurred. Therefore, the original sample would have been cut in half three times.

$$\text{fraction remaining} = \text{original sample} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$$
$$= \text{original sample} \times \frac{1}{8}$$

Only $\frac{1}{8}$ of the original sample would remain.

Note that the equation can also be used to solve this problem.

$$N_o = 100\% \qquad N = N_o\left(\frac{1}{2}\right)^n$$
$$n = 6 \div 2 = 3$$
$$N = ? \qquad = 100\%\left(\frac{1}{2}\right)^3$$
$$= 12.5\%$$

9. a. Step 1: Find the mass of all the nuclear components.

$$\begin{aligned} \text{mass of 6 protons} &= 6\left(1.673\,53\times10^{-27}\text{ kg}\right) = 1.004\,118\times10^{-26}\text{ kg} \\ +\text{mass of 6 neutrons} &= 6\left(1.674\,92\times10^{-27}\text{ kg}\right) = 1.004\,952\times10^{-26}\text{ kg} \\ \hline \text{total mass of nuclear components} &= 2.009\,07\times10^{-26}\text{ kg} \end{aligned}$$

Step 2: The mass defect is the mass of the components minus the mass of the nucleus.

$$\begin{aligned} &2.009\,07\times10^{-26}\text{ kg} \\ &-1.992\,64\times10^{-26}\text{ kg} \\ \hline &1.643\times10^{-28}\text{ kg} \end{aligned}$$

b. $E = mc^2$

$$= \left(1.643\times10^{-28}\text{ kg}\right)\left(3.00\times10^{8}\text{ m/s}\right)^2$$
$$= 1.48\times10^{-11}\text{ J}$$

10. Step 1: Find the total mass of the reactants.

$$\begin{aligned} \text{mass of U 235} &= 390.299\,81\times10^{-27}\text{ kg} \\ +\text{mass of 1 neutron} &= 1.674\,92\times10^{-27}\text{ kg} \\ \hline &391.974\,73\times10^{-27}\text{ kg} \end{aligned}$$

Step 2: Find the total mass of the products.

$$\begin{aligned} \text{mass of Sr 90} &= 149.295\,41\times10^{-27}\text{ kg} \\ \text{mass of Xe 136} &= 225.679\,38\times10^{-27}\text{ kg} \\ \text{mass of 10 neutrons} &= 16.749\,20\times10^{-27}\text{ kg} \\ \hline &391.723\,99\times10^{-27}\text{ kg} \end{aligned}$$

Step 3: Calculate the mass that was converted to energy.

$$\begin{aligned} &391.974\,73\times10^{-27}\text{ kg} \\ &-391.723\,99\times10^{-27}\text{ kg} \\ \hline \text{change in mass} &= 0.250\,74\times10^{-27}\text{ kg} \\ &= 2.5074\times10^{-28}\text{ kg} \end{aligned}$$

Step 4: Calculate the energy released.

$$E = mc^2$$
$$= \left(2.5074\times10^{-28}\text{ kg}\right)\left(3.00\times10^{8}\text{ m/s}\right)^2$$
$$= 2.26\times10^{-11}\text{ J}$$

Section 2: Living with Risks

This section introduces the ideas of risk assessment and risk perception. The main theme that runs through this section is that since the process of producing a risk assessment is so very different from the process of forming a risk perception, the outcomes of these approaches are often quite divergent. Students are encouraged to see the value in both approaches and to understand the importance of dialogue between those that hold conflicting views.

Section 2: Assignment Answer Key (40 marks)

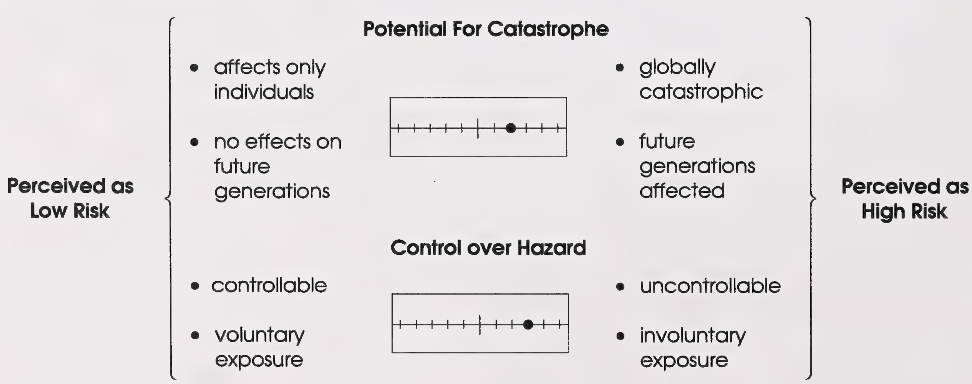
1. The following chart best answers this question.

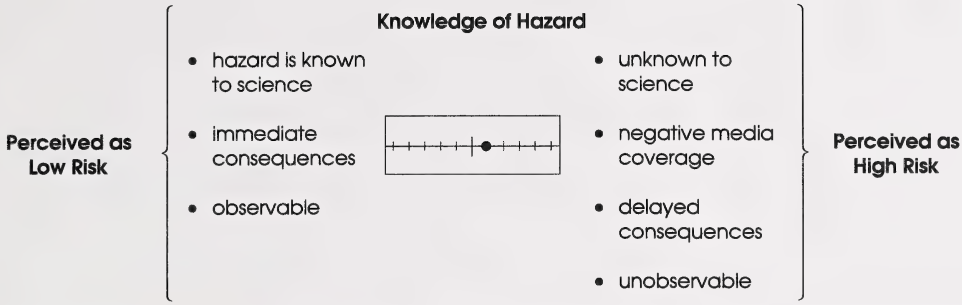
	Risk Assessment	Risk Perception
Who does this?	experts	members of the general public
How is this done?	statistical analysis	thinking about factors that influence the perception of risk
What is produced?	a statistical assessment of risk	a judgement in the mind of the person

2. Students should choose **two** of the following:

- This statistic is beyond the limit of understanding for most people, since anything smaller than 1 in 10 000 becomes meaningless.
- If their opinion is based on a risk perception, there may be a significant sense of dread due to the potential for catastrophe, the lack of control over the hazard, and the lack of knowledge of the hazard. This perception of dread is unlikely to change due to one statistic.
- Deeply held opinions are very difficult to change.
- The level of suspicion and mistrust of the experts by some members of society may detract from their willingness to accept this statistic as being valid.

3. a. The following answers provide one example of many possibilities.





b. Flying as a passenger in a commercial airliner has a great potential for catastrophe since hundreds of people can be killed in a very short time. These types of accidents also give the passenger little chance of controlling the outcome, since the accidents usually involve the whole aircraft falling to the ground. Although the hazard is known and is observable, negative media coverage of crash sites has left a deep, negative impression on many people.

4. The following answers show likely answers for each topic. These are not the only answers for each topic. Although student responses should be graded according to the criteria described in the instructions given, and not solely upon the particular opinion stated, the best answers will likely disagree with each topic since these positions are easier to support.

Topic A

In this essay I will explain why I disagree with the statement given under Topic A. A Chernobyl-type accident could never happen in a CANDU 3 reactor due to the design differences between this reactor and the Soviet RBMK reactor.

This first major difference in design concerns the use of graphite blocks as the moderator in the Soviet reactor. The graphite blocks allow the process of fission to continue even if safe operating temperatures have been exceeded and the water has boiled away. In fact, if the water does boil away, the reactor core heats up even more. In contrast, CANDU 3 reactors use heavy water as the moderator. This means that if safe operating temperatures are exceeded and the water boils away, the process of fission will slow down by itself since it can't continue without a moderator.

The second major difference in design is the lack of a containment building at the Chernobyl nuclear plant. Had a containment building been in place, the large cloud of radioactive materials would not have been released into the environment. CANDU 3 reactors incorporate a containment building as part of their basic design.

The accident at Chernobyl was primarily due to a combination of operator error and poor design. Although the potential for human error can never be entirely eliminated from any system, the superior design of the CANDU 3 reactors make accidents on the scale of Chernobyl a virtual impossibility.

Topic B

In this essay I will explain why I disagree with the statement given under Topic B. **Both** coal-fired and nuclear generating stations have environmental problems, making it unclear whether one is clearly the better environmental choice than the other.

The environmental problems associated with using coal to generate electricity stem largely from the emissions released when coal is burned. Carbon dioxide is a greenhouse gas that is thought to contribute to global warming. Although the extent of the problems related to global warming is still being debated, many scientists would argue that the environmental consequences will be severe. Other emissions include sulfur dioxide and nitrous oxide, which both cause acid rain. Acid rain causes chemical changes in soils and bodies of water. It alters ecosystems permanently by reducing soil fertility. Many other compounds, such as small particles of carbon (soot) and heavy metals, are also released into the atmosphere when coal is burned. Smog, asthma, and some forms of cancer have been linked to these emissions. Clearly the burning of coal does create problems for the environment.

Nuclear power plants also have the potential for a negative impact on the environment. In this case, it is the disposal of nuclear waste that causes the greatest concern. The spent fuel is actually more radioactive than the original fuel because it contains so many different radioactive isotopes, all in various stages of radioactive decay, continually emitting all three types of nuclear radiation. Although it was originally thought that the spent fuel could be reprocessed, such a method has not yet been devised. In Canada the spent fuel must be stored in special facilities. Some experts maintain that even the nuclear power plant itself will eventually need to be dismantled or sealed tight because the building materials will themselves become radioactive and structurally flawed due to the prolonged exposure to radiation. The reason that there is such concern over these radioactive materials is that the radiation must not be allowed to escape into the environment and enter the food chain. When even trace amounts of radioactive materials are exposed to living cells, the cells can become defective and/or die. The release of radioactive materials into the environment can create long-term environmental problems.

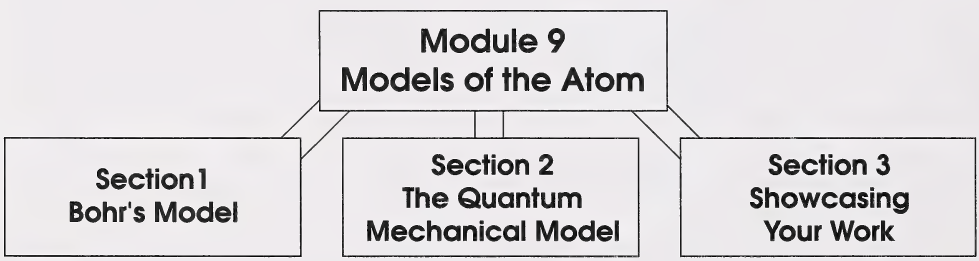
In conclusion, it can be seen that both methods of generating electricity have environmental problems. Rather than wonder which method produces the least damage, it might be better to focus on conservation techniques that allow Canadians to use less electricity in the first place.

Module 9: Models of the Atom

Overview

This module is the culminating module for the whole course. Although the principal focus is the Rutherford and Bohr models of the atom, this module relies heavily on key concepts from virtually all of the earlier modules. These previously studied concepts are also incorporated in the main STS connection that is used throughout the module – lighting. Both neon-type signs and standard fluorescent tubes are investigated by students from as many different points of view as possible. These STS connections provide students with a vehicle to review and prepare for their diploma exam.

The last section of the module is dedicated exclusively to the development of skills that will help students to be successful on their exam.



Materials and Equipment

The following is a list of materials and equipment necessary for an individual to complete the investigations and activities in Module 9. Adjust the amount of equipment if more than one individual is involved.

Section 1: Activity 2

Investigation: Spectral Analysis of Lighting

- hand-held quantitative spectroscope (has a scale inside to measure wavelengths)
- pull-out page from the Appendix of this module (A copy of this sheet that you can use as a master for photocopying can be found at the end of this LFM.)
- access to a light fixture that uses a standard tungsten filament light bulb
- access to a light fixture that uses fluorescent tubes

- access to a number of different coloured neon signs (These can be found in malls, large grocery stores, or in the windows of shops.)

Additional Resources

The same resources listed for Module 1 can provide additional support and information for teaching Module 9. Please refer to the list presented for Module 1.

Possible Media

Videocassettes – *Structure of the Atom*: *The Rutherford Model*
The Bohr Model
Spectra
The Wave Mechanical Model

These ten-minute programs were originally produced by TV Ontario and are available through the ACCESS Network.

Note: Some of the suggested media may not be authorized by Alberta Education. Teachers should use their own discretion regarding the use of these resources in their classroom.

Evaluation

The evaluation of this module will be based on three assignments:

Section 1 Assignment	36%
Section 2 Assignment	30%
Section 3 Assignment	34%
TOTAL	100%

Section 1: Bohr's Model

This section guides students through the historical development of Bohr's model of the atom. Students have an excellent opportunity within this section to gain insight into the nature of science as they examine the development of a scientific model. One of the most important things to stress here is that theories in science are nothing more than tentative best answers. Students often hold the view that science is purely factual information that is unchanging.

This section also provides students with an opportunity to investigate the spectra from different forms of lighting. The students will build on these experiences in the next section when they look at the processes used in fluorescent lighting.

Section 1: Assignment Answer Key (36 marks)

1. Textbook question 1:

   The atoms high in the atmosphere are gaseous and are under low pressure. Since they are being excited by high-energy charges, this is very similar to the circumstances in a gas discharge tube. It follows that the light emitted should be a line spectrum.

2. Textbook question 2:

   The spectrum will not be continuous because the gases in Earth's atmosphere will absorb some of the wavelengths of light. The result will be an absorption spectrum.

3. Alpha particle data:

$$m = 6.65 \times 10^{-27} \text{ kg}$$
$$q = +3.20 \times 10^{-19} \text{ C}$$
$$\begin{aligned} E_k &= 4.0 \text{ MeV} \\ &= 4.0 \times 10^{6} \text{ eV} \\ &= 4.0 \times 10^{6} \text{ eV}\left[\frac{1.60 \times 10^{-19} \text{ J}}{1 \text{ eV}}\right] \\ &= 6.40 \times 10^{-13} \text{ J} \end{aligned}$$

Platinum nucleus data:

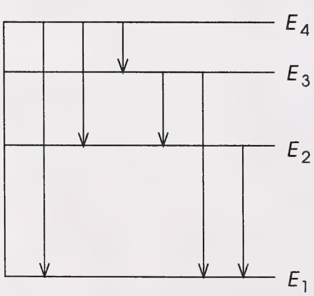
$$\begin{aligned} q &= 78\left(+1.60 \times 10^{-19} \text{ C}\right) \\ &= 1.248 \times 10^{-17} \text{ C} \end{aligned}$$

$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p{}' + E_k{}'$$
$$0 + E_k = \frac{kq_1q_2}{r} + 0$$
$$r = \frac{kq_1q_2}{E_k}$$
$$r = \frac{\left(8.99 \times 10^{9} \text{ N}\bullet\text{m}^2/\text{C}^2\right)\left(3.20 \times 10^{-19} \text{ C}\right)\left(1.248 \times 10^{-17} \text{ C}\right)}{\left(6.40 \times 10^{-13} \text{ J}\right)}$$
$$= 5.6 \times 10^{-14} \text{ m}$$

4. Textbook question 4:

This photon will not be absorbed by the atom. The photon can only be absorbed if there is an energy level that is exactly 6.2 eV above the ground state. No such level exists.

5. Textbook question 5:



There are six possible transitions, as shown in the diagram to the left. The transition that produces the photon with the greatest energy is E_4 to E_1.

6. Textbook question 6:

$$E_{photon} = 14.0 \text{ eV}$$
$$\Delta E_{atom} = 13.6 \text{ eV}$$
$$E_k{}' = ?$$

$$\sum E_{before} = \sum E_{after}$$
$$E_{photon} = \Delta E_{atom} + E_k{}'$$
$$\begin{aligned} E_k{}' &= E_{photon} - \Delta E_{atom} \\ &= 14.0 \text{ eV} - 13.6 \text{ eV} \\ &= 0.4 \text{ eV} \end{aligned}$$

7. Textbook question 15:

$$E_i = ?$$
$$E_f = E_1 = -13.6 \text{ eV}$$
$$\lambda = 9.38 \times 10^{-8} \text{ m}$$
$$E_{light} = ?$$

Step 1:

$$E_{light} = \Delta E$$
$$\frac{hc}{\lambda} = \Delta E$$
$$\begin{aligned} \Delta E &= \frac{hc}{\lambda} \\ &= \frac{(6.63 \times 10^{-34} \text{ J} \bullet \text{s})(3.00 \times 10^{8} \text{ m/s})}{(9.38 \times 10^{-8} \text{ m})} \\ &= 2.120 \times 10^{-18} \text{ J} \\ &= 2.120 \times 10^{-18} \text{ J}\left[\frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}\right] \\ &= 13.25 \text{ eV} \end{aligned}$$

Step 2:

$$\Delta E = E_i - E_f$$
$$\begin{aligned} E_i &= \Delta E + E_f \\ &= 13.25 \text{ eV} + (-13.6 \text{ eV}) \\ &= -0.35 \text{ eV} \end{aligned}$$

Step 3:

$$E_n = \frac{1}{n^2} E_1$$
$$\begin{aligned} n^2 &= \frac{E_1}{E_n} \\ &= \frac{-13.6 \text{ eV}}{-0.35 \text{ eV}} \\ &= 38.9 \end{aligned}$$
$$n = 6.23$$

Since n can only have integer values, the initial energy level was probably E_6.

8. Textbook question 16.a.:

$$r_1 = 5.29 \times 10^{-11} \text{ m}$$
$$n = 3$$
$$r_3 = ?$$

$$\begin{aligned} r_3 &= n^2 r_1 \\ &= (3)^2 (5.29 \times 10^{-11} \text{ m}) \\ &= 4.76 \times 10^{-10} \text{ m} \end{aligned}$$

Textbook question 16.b.:

$r_3 = 4.76 \times 10^{-10}$ m

$q = 1.60 \times 10^{-19}$ C

$F_e = ?$

$$F_e = \frac{kqq}{r^2}$$
$$= \frac{\left(8.99 \times 10^9 \text{ N} \bullet \text{m}^2/\text{C}^2\right)\left(1.60 \times 10^{-19} \text{ C}\right)\left(1.60 \times 10^{-19} \text{ C}\right)}{\left(4.76 \times 10^{-10} \text{ m}\right)^2}$$
$$= 1.016 \times 10^{-9} \text{ N}$$
$$= 1.02 \times 10^{-9} \text{ N}$$

Textbook question 16.c.:

$a_c = ?$

$F_e = 1.016 \times 10^{-9}$ N

$m = 9.11 \times 10^{-31}$ kg

$$F_c = F_e$$
$$ma_c = F_e$$
$$a_c = \frac{F_e}{m}$$
$$= \frac{1.016 \times 10^{-9} \text{ N}}{9.11 \times 10^{-31} \text{ kg}}$$
$$= 1.12 \times 10^{21} \text{ m/s}^2$$

Textbook question 16.d.:

$F_e = 1.02 \times 10^{-9}$ N

$m = 9.11 \times 10^{-31}$ kg

$v = ?$

$$F_c = F_e$$
$$\frac{mv^2}{r} = F_e$$
$$v^2 = \frac{F_e r}{m}$$
$$v = \sqrt{\frac{F_e r}{m}}$$
$$= \sqrt{\frac{\left(1.02 \times 10^{-9} \text{ N}\right)\left(4.76 \times 10^{-10} \text{ m}\right)}{9.11 \times 10^{-31} \text{ kg}}}$$
$$= 7.30 \times 10^5 \text{ m/s}$$

Alternative method:

$v_1 = 2.18 \times 10^6$ m/s

$n = 3$

$v_3 = ?$

$$v_3 = \frac{v_1}{n}$$
$$= \frac{2.18 \times 10^6 \text{ m/s}}{3}$$
$$= 7.27 \times 10^5 \text{ m/s}$$

$$\frac{v}{c} = \frac{7.3 \times 10^5 \text{ m/s}}{3.00 \times 10^8 \text{ m/s}}$$
$$= 0.0024$$

The speed of the electron is about 0.24% of the speed of light.

9.

$$E_{light} = \Delta E_{atom}$$

Bohr's second postulate

$$E_{light} = E_i - E_f$$

$$E_i = \frac{1}{{n_i}^2} E_1$$

Substitute.

$$E_f = \frac{1}{{n_f}^2} E_1$$

Substitute.

$$E_{light} = \frac{1}{{n_i}^2} E_1 - \frac{1}{{n_f}^2} E_1$$

Rearrange.

$$E_{light} = E_1 \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2} \right)$$

Einstein's equation:

$$E_{light} = \frac{hc}{\lambda}$$

Substitute.

$$\frac{hc}{\lambda} = E_1 \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2} \right)$$

Rearrange.

$$\frac{1}{\lambda} = \frac{E_1}{hc} \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2} \right)$$

Substitute values from Physics 30 data sheets.

$$\frac{1}{\lambda} = \frac{\left(-2.18 \times 10^{-18}\ \text{J}\right)}{\left(6.63 \times 10^{-34}\ \text{J} \bullet \text{s}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)} \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2} \right)$$

Simplify.

$$\frac{1}{\lambda} = \left(-1.10 \times 10^{7}\ \text{m}^{-1}\right) \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2} \right)$$

Since R_H is positive, the negative sign needs to be moved to the second factor.

Multiply both factors on the right-hand side of the equal sign by -1.

$$\frac{1}{\lambda}=\left(1.10\times10^{7}\ \text{m}^{-1}\right)\left(\frac{1}{n_f^{\,2}}-\frac{1}{n_i^{\,2}}\right)$$

$$\Downarrow$$

$$\frac{1}{\lambda}=R_H\left(\frac{1}{n_f^{\,2}}-\frac{1}{n_i^{\,2}}\right) \xleftarrow{\text{Substitute.}} R_H=1.10\times10^{7}\ \text{m}^{-1}$$

Section 2: The Quantum Mechanical Model

This section uses the topic of fluorescent lighting as an STS connection for quantum mechanical models of the atom and as a vehicle for reviewing many of the ideas from previous modules. At first glance it may seem that the study of fluorescent lighting is done in too much detail for just one STS connection. However, this topic is perfectly placed to give students practice linking major concepts from earlier in the course in a relevant context, which is likely to be the characteristic style of many questions on their diploma exam. The focus of this section for students should be the application and linking of major concepts from across the course.

Section 2: Assignment Answer Key (30 marks)

1. Bohr's model could not answer the following questions:

    - Why are some spectral lines brighter than others?
    - Why do magnetic fields cause some lines to split?
    - Why must angular momentum be quantized?
    - Why don't orbiting electrons in stationary states emit radiation?

    The wave mechanical model gave systematic, consistent answers to these questions.

2. The wave mechanical model is based on a probability and statistical approach applied to the electron matter waves that surround the nucleus. This is a very abstract approach that cannot be directly compared to large-scale objects because they do not behave this way.

3. a. Low-pressure sodium street lamps produce an emission spectrum. This is shown in the graph by the discrete wavelengths of light.

    b. The overall colour of the light from these street lamps is yellow. The large central spike at 590 nm is overwhelmingly more powerful than the others in the red and green parts of the spectrum. Despite the presence of these other colours, the overall colour of light produced is yellow.

c. Step 1: Solve for E_2.

Since the wavelength is longer, it must be the lower of the two energy levels, E_2.

$\lambda = 5.896 \times 10^{-7}$ m
$E_1 = -5.140$ eV
$c = 2.9979 \times 10^{8}$ m/s
$h = 6.6261 \times 10^{-34}$ J•s
$1 \text{ eV} = 1.6022 \times 10^{-19}$ J
$\Delta E = ?$
$E_2 = ?$

$$
\begin{aligned}
E_{light} &= \Delta E \\
\frac{hc}{\lambda} &= \Delta E \\
\Delta E &= \frac{hc}{\lambda} \\
&= \frac{\left(6.6261 \times 10^{-34} \text{ J}\bullet\text{s}\right)\left(2.9979 \times 10^{8} \text{ m/s}\right)}{\left(5.896 \times 10^{-7} \text{ m}\right)} \\
&= 3.369\,12 \times 10^{-19} \text{ J} \times \left[\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}}\right] \\
&= 2.103 \text{ eV}
\end{aligned}
$$

$$
\begin{aligned}
\Delta E &= E_2 - E_1 \\
E_2 &= E_1 + \Delta E \\
&= (-5.140 \text{ eV}) + (2.103 \text{ eV}) \\
&= -3.037 \text{ eV}
\end{aligned}
$$

Step 2: Solve for E_3.

$\lambda = 5.890 \times 10^{-7}$ m
$E_1 = -5.140$ eV
$\Delta E = ?$
$E_3 = ?$

$$
\begin{aligned}
E_{light} &= \Delta E \\
\frac{hc}{\lambda} &= \Delta E \\
\Delta E &= \frac{hc}{\lambda} \\
&= \frac{\left(6.6261 \times 10^{-34} \text{ J}\bullet\text{s}\right)\left(2.9979 \times 10^{8} \text{ m/s}\right)}{\left(5.890 \times 10^{-7} \text{ m}\right)} \\
&= 3.372\,56 \times 10^{-19} \text{ J} \times \left[\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}}\right] \\
&= 2.105 \text{ eV}
\end{aligned}
$$

$$
\begin{aligned}
\Delta E &= E_3 - E_1 \\
E_3 &= E_1 + \Delta E \\
&= (-5.140 \text{ eV}) + (2.105 \text{ eV}) \\
&= -3.035 \text{ eV}
\end{aligned}
$$

4. The posters are painted with pigments that are capable of fluorescence. When an ultraviolet photon lands on the atoms in these pigments, the energy is absorbed and then re-emitted as a visible photon. The pigments in these posters are specially designed to release mainly one colour of photon, so the colours on the poster come across as being particularly vibrant.

5. a. The Cool White bulb would be better because less light is emitted by the bulb from the red-orange-yellow region of the spectrum and more light is emitted from the violet-blue-green end of the spectrum. This bulb would tend to make the dresses look less yellowed, since there would be less light from this end of the spectrum for the dresses to reflect.

   b. If the claim is true, the spot remover fluoresces by absorbing ultraviolet light and reemitting blue light. The energy of the ultraviolet light is absorbed by the molecules of the spot remover and is then reradiated as visible blue light. Since energy is conserved, the difference in these energies must be absorbed by the spot-removing molecules as thermal energy.

Section 3: Showcasing Your Work

The focus of this section is getting students prepared, both in terms of skills and attitude, for writing their diploma exam. The strategies offered to students in this section are based on the idea that success is defined in terms of doing your personal best. This implies that students not only have a true understanding of the major concepts, but it also means that students have the proper attitude towards the exam. It is crucial that students stay calm and positive when attempting challenging problems on their exam. It's been said that success in solving difficult problems on an exam depends more on the mindset of a well-prepared student than on computational skills that they may have.

Section 3: Assignment Answer Key (34 marks)

1. **C**

2. **A**

3. **B**

4. **A**

5. **D**

6. **C**

7. $m = 6.00\ \text{kg}$
$h = 4.50\ \text{m}$
$v' = ?$

$$\sum E_{before} = \sum E_{after}$$
$$E_p + E_k = E_p{}' + E_k{}'$$
$$mgh + 0 = 0 + \frac{1}{2}m(v')^2$$
$$v' = \sqrt{2gh}$$
$$= \sqrt{2(9.81\ \text{m/s}^2)(4.50\ \text{m})}$$
$$= 9.40\ \text{m/s}$$

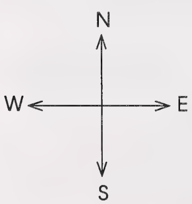
The answer is 9.40.

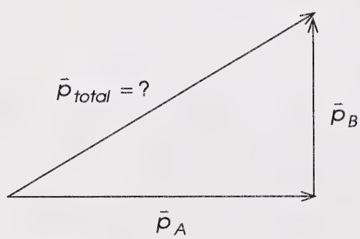
8. $I = 1.5\ \text{A}$
$V = 120\ \text{V}$
$t = 10\ \text{min} = 600\ \text{s}$
$E = ?$

$$P = IV$$
$$\frac{E}{t} = IV$$
$$E = IVt$$
$$= (1.5\ \text{A})(120\ \text{V})(600\ \text{s})$$
$$= 1.08 \times 10^5\ \text{J}$$

The answer is 1.1.

9.





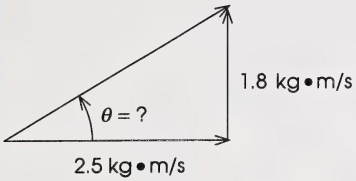
$$\vec{p}_A = m_A \vec{v}_A$$
$$= (1.25\ \text{kg})(2.00\ \text{m/s, east})$$
$$= 2.50\ \text{kg}\bullet\text{m/s, east}$$

$$\vec{p}_B = m_B \vec{v}_B$$
$$= (1.80\ \text{kg})(1.00\ \text{m/s, north})$$
$$= 1.80\ \text{kg}\bullet\text{m/s, north}$$

$$C^2 = A^2 + B^2$$
$$(p_{total})^2 = (p_A)^2 + (p_B)^2$$
$$= (2.50\ \text{kg}\bullet\text{m/s})^2 + (1.80\ \text{kg}\bullet\text{m/s})^2$$
$$= 9.49\ (\text{kg}\bullet\text{m/s})^2$$
$$p_{total} = 3.08\ \text{kg}\bullet\text{m/s}$$

The answer is 3.08.

10.



$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{1.8\ \text{kg}\bullet\text{m/s}}{2.5\ \text{kg}\bullet\text{m/s}}$$
$$\theta = 35.8°$$

The answer is 35.8.

11. $m = 6.65\times10^{-27}$ kg

$q = 3.20\times10^{-19}$ C

$E_k = 1.36\times10^{-13}$ J

$B_\perp = 4.60\times10^{-3}$ T

$F_m = ?$

$$E_k = \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2E_k}{m}}$$
$$= \sqrt{\frac{2\left(1.36\times10^{-13}\ \text{J}\right)}{6.65\times10^{-27}\ \text{kg}}}$$
$$= 6.3955\times10^{6}\ \text{m/s}$$

$$F_m = qvB$$
$$= \left(3.20\times10^{-19}\ \text{C}\right)\left(6.3955\times10^{6}\ \text{m/s}\right)\left(4.60\times10^{-3}\ \text{T}\right)$$
$$= 9.41\times10^{-15}\ \text{N}$$

The answer is 9.41.

12. Charge the rubber rod by rubbing it vigorously with the fur. This will cause the rod to become negatively charged. The rubber rod can then be used to charge the electroscope negatively by touching it to the knob of the electroscope. The leaves of the electroscope will diverge because they are both negatively charged and are repelling each other.

The charge on the sphere can now be determined using the electroscope. The electroscope should be brought close to the sphere but should not be touching it. If the leaves of the electroscope diverge further, the sphere is negatively charged since it is repelling more negative charges down into the leaves. If the leaves start to collapse, the sphere is positively charged since it is attracting the negative charges on the leaves to the knob of the electroscope, making the leaves less negative.

13. a. For energy conservation! The voltage is increased because at higher voltage there is less current flow. Less current flow means less energy lost to heating effects in the transmission wires. Heating losses are determined by $P = I^2R$ so lower current means that less energy is wasted.

b.
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$
$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$
$$\frac{N_s}{N_p} = \frac{6.60\times10^{5}\ \text{V}}{1.20\times10^{3}\ \text{V}}$$
$$\frac{N_s}{N_p} = \frac{550}{1}$$

c. AC current permits the use of transformers to step up or step down voltage. As described in the answer to question 13. a., this allows for electric energy to be transferred efficiently from the power plant to your home with minimal losses due to the heating of the transmission lines.

DC current cannot be stepped up or down by a transformer because the transformer relies on an AC source to create a changing magnetic flux within its core.

14. Students should be awarded full marks for keeping accurate records.

15. a., b., c. Students should be awarded full marks for making comments consistent with the data on their spreadsheet.

Final Test

Included here is the answer key to the final test and the student's copy of the final test which is designed for photocopying and possible faxing.

Note:

The answer key and student's copy of this final test should be kept secure by the teacher. Students should not have access to this test until it is assigned in a supervised situation. The answers should be stored securely and retained by the teacher at all times.

PHYSICS 30

FINAL TEST ANSWER KEY

Part A: Multiple Choice (35 marks)

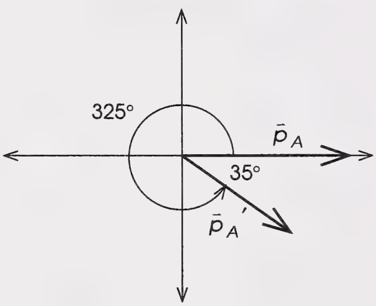
1.	B	8.	B	15.	B	22.	A	29.	C
2.	A	9.	C	16.	A	23.	C	30.	D
3.	D	10.	A	17.	A	24.	A	31.	A
4.	A	11.	A	18.	C	25.	D	32.	B
5.	B	12.	B	19.	D	26.	A	33.	C
6.	C	13.	A	20.	D	27.	D	34.	C
7.	C	14.	D	21.	B	28.	C	35.	C

Part B: Numerical Response (14 marks)

1.	1.75	4.	33.7	7.	1	10.	8.1	13.	2.00
2.	2	5.	1.00	8.	2.5	11.	3.76	14.	3
3.	7.4	6.	1.68	9.	3	12.	4.95		

Part C: Written Response (21 marks)

1.



$$\vec{p}_A = (10\ \text{kg})(5.0\ \text{m/s at } 0°)$$
$$= 50\ \text{kg} \bullet \text{m/s at } 0°$$

$$\vec{p}_A{}' = (10\ \text{kg})(4.0\ \text{m/s at } 325°)$$
$$= 40\ \text{kg} \bullet \text{m/s at } 325°$$

Components:

$\vec{p}_A = 50\ \text{kg} \bullet \text{m/s at } 0°$

$$p_{A_x} = 50\ \text{kg} \bullet \text{m/s}$$
$$p_{A_y} = 0$$

$\vec{p}_A{}' = 40\ \text{kg} \bullet \text{m/s at } 325°$

$$p_{A_x}{}' = (40\ \text{kg} \bullet \text{m/s})(\cos 325°)$$
$$= 32.8\ \text{kg} \bullet \text{m/s}$$

$$p_{A_y}{}' = (40\ \text{kg} \bullet \text{m/s})(\sin 325°)$$
$$= -22.9\ \text{kg} \bullet \text{m/s}$$

The law of conservation of momentum can be applied to the *x*- and *y*-components.

$$\sum(p_x)_{before} = \sum(p_x)_{after}$$

$$p_{A_x} = p_{A_x}' + p_{B_x}'$$

$$\sum(p_y)_{before} = \sum(p_y)_{after}$$

$$p_{A_y} = p_{A_y}' + p_{B_y}'$$

$$\begin{aligned} p_{B_x}' &= p_{A_x} - p_{A_x}' \\ &= (50\ \text{kg}\bullet\text{m/s}) - (32.8\ \text{kg}\bullet\text{m/s}) \\ &= 17.2\ \text{kg}\bullet\text{m/s} \end{aligned}$$

$$\begin{aligned} p_{B_y}' &= p_{A_y} - p_{A_y}' \\ &= 0 - (-22.9\ \text{kg}\bullet\text{m/s}) \\ &= 22.9\ \text{kg}\bullet\text{m/s} \end{aligned}$$

$$\begin{aligned} p_B' &= \sqrt{p_{B_x}'^2 + p_{B_y}'^2} \\ &= \sqrt{(17.2\ \text{kg}\bullet\text{m/s})^2 + (22.9\ \text{kg}\bullet\text{m/s})^2} \\ &= 29\ \text{kg}\bullet\text{m/s} \end{aligned}$$

$$\begin{aligned} \tan\theta &= \frac{p_{B_y}'}{p_{B_x}'} \\ &= \frac{(22.9\ \text{kg}\bullet\text{m/s})}{(17.2\ \text{kg}\bullet\text{m/s})} \\ \theta &= 53^\circ \end{aligned}$$

$$\boxed{\vec{p}_B' = 29\ \text{kg}\bullet\text{m/s at } 53^\circ}$$

2. Half-life is the time for the activity of the sample to become half as much. Therefore, sample the data on the graph and average the values to determine the best value.

Change in Activity (counts/s)	Time (s)
240 to 120	$102 - 27 = 75$
200 to 100	$124 - 44 = 80$
160 to 80	$150 - 68 = 82$
120 to 60	$184 - 102 = 82$
100 to 50	$204 - 124 = 80$
60 to 30	$258 - 184 = 74$
40 to 20	$297 - 228 = 69$

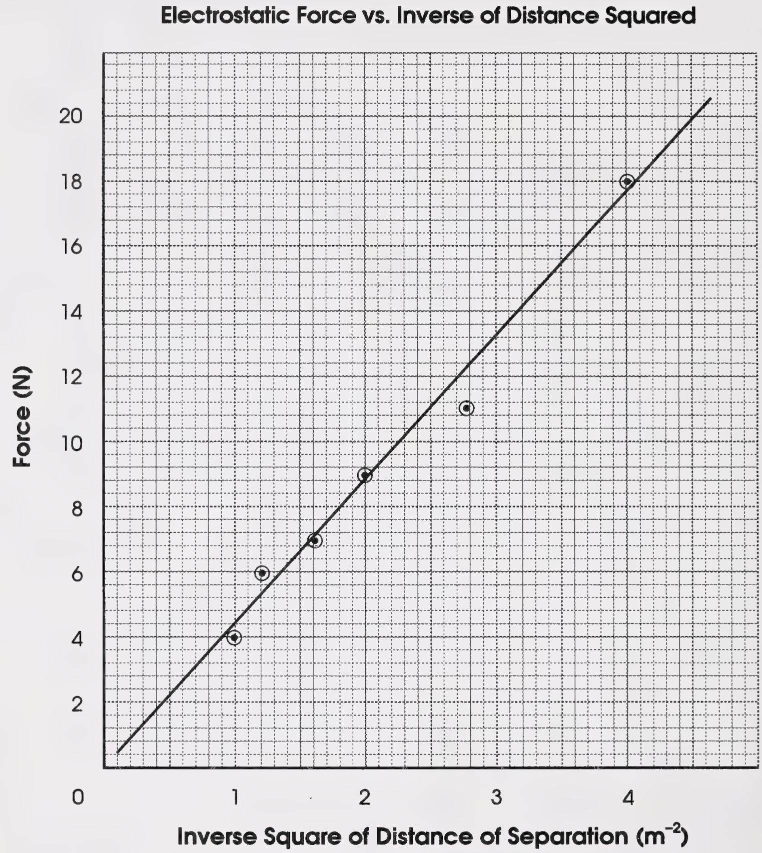
$$\begin{aligned} \text{average} &= \frac{542\ \text{s}}{7} \\ &= 77.4\ \text{s} \\ &= 77\ \text{s} \end{aligned}$$

Key:

- Correctly sampling two points and correctly determining a half-life
- Correctly sampling and determining more than one half-life
- Correctly using an averaging technique
- Obtaining an answer of 77 ± 5 s

3. a. Using the equation $F_e = \frac{kqq}{r^2}$, a straight-line graph should result if F_e is plotted against $\frac{1}{r^2}$.

F_e (N)	$\frac{1}{r^2}$ (m^{-2})
18	4.0
11	$2.\overline{7}$
9	2.0
7	1.6
6	1.2
4	1.0



b.
$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{17.2\ \text{N} - 4.0\ \text{N}}{3.9\ \text{m}^{-2} - 0.9\ \text{m}^{-2}}$$
$$= \frac{13.2\ \text{N}}{3.0\ \text{m}^{-2}}$$
$$= 4.4\ \text{N} \cdot \text{m}^2$$

c.

$$\boxed{F_e = \frac{kq_1q_2}{r^2}}$$

The spheres are identical, so $q_1 = q_2$.

$$\boxed{F_e = \frac{kq^2}{r^2}}$$

$$\boxed{F_e = \underbrace{kq^2}\left(\frac{1}{r^2}\right)}$$

By inspection it can be shown that the slope of the line equals kq^2.

$$\boxed{y = m \quad x + b}$$

$$\text{slope} = kq^2$$
$$q^2 = \frac{\text{slope}}{k}$$
$$q = \sqrt{\frac{\text{slope}}{k}}$$
$$= \sqrt{\frac{4.4\ \text{N}\bullet\text{m}^2}{8.99\times10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$$
$$= 2.2\times10^{-5}\ \text{C}$$

If the students used the value for slope that was provided $\left(3.9\ \text{N}\bullet\text{m}^2\right)$, the value for charge should be $2.1\times10^{-5}\ \text{C}$.

4. a. The electrodes at either end of the sign create an electric field in the tube using the voltage supplied by the transformer. The electrons in the tube respond to this field and gain kinetic energy. When the electrons collide with the gaseous atoms in the tube, the atoms gain energy and send an electron to a higher energy level. When the electron returns to a lower energy state, light energy is emitted.

b. Choose any wavelength from the spectrum recorded by Nicole.

$\lambda = 6.10\times10^{-7}\ \text{m}$
$E_{light} = ?$
$\Delta E = ?$

$$\Delta E_{atom} = E_{light}$$
$$= \frac{hc}{\lambda}$$
$$= \frac{\left(6.63\times10^{-34}\ \text{J}\bullet\text{s}\right)\left(3.00\times10^{8}\ \text{m/s}\right)}{\left(6.10\times10^{-7}\ \text{m}\right)}$$
$$= 3.26\times10^{-19}\ \text{J}$$

Note that any other wavelength correctly calculated could also be accepted. The following table summarizes the other possible wavelengths and energy values:

c. $P_s = 450 \text{ W}$

$E = ?$

$t = 1.00 \text{ s}$

$$P = \frac{E}{t}$$

$$\begin{aligned} E &= Pt \\ &= (450 \text{ J/s})(1.00 \text{ s}) \\ &= 450 \text{ J} \end{aligned}$$

d. $$\begin{aligned} E_{light} &= 0.25(E_{electric}) \\ &= 0.25(450 \text{ J}) \\ &= 112.5 \text{ J} \end{aligned}$$

This is the total energy radiated by all the photons that leave the glass tube in one second. To estimate the number of photons, it is necessary to pick a representative photon and calculate its energy. A good photon to choose would be between 6.0×10^{-7} m and 6.5×10^{-7} m since this is where most of them cluster.

$\lambda = 6.3 \times 10^{-7} \text{ m}$

$$\begin{aligned} E_{photon} &= \frac{hc}{\lambda} \\ &= \frac{(6.63 \times 10^{-34} \text{ J}\bullet\text{s})(3.00 \times 10^{8} \text{ m/s})}{(6.30 \times 10^{-7} \text{ m})} \\ &= 3.2 \times 10^{-19} \text{ J} \end{aligned}$$

(total light energy) = (number of photons)(average energy per photon)

$$\begin{aligned} 112.5 \text{ J} &= N(3.2 \times 10^{-19} \text{ J}) \\ N &= \frac{112.5 \text{ J}}{3.2 \times 10^{-19} \text{ J}} \\ &= 3.5 \times 10^{20} \text{ photons} \end{aligned}$$

Note that a number of acceptable answers can be provided for this question if the values are consistent with the wavelengths. The answers should be within the following range for the wavelengths that were provided: 2.7×10^{20} photons to 4.0×10^{20} photons.

PHYSICS 30

FINAL TEST

GENERAL INSTRUCTIONS

YOU HAVE **TWO-AND-ONE-HALF** HOURS TO COMPLETE THIS TEST. Work through the entire test answering the questions you are sure you know. You will then be able to concentrate on the questions of which you are not quite sure.

TOTAL MARKS: 70

PART A: Multiple Choice	35 marks
PART B: Numerical Response	14 marks
PART C: Written Response	21 marks

The Physics 30 data sheets are provided for your reference. You are expected to provide your own scientific calculator.

Value

PART A: MULTIPLE CHOICE

35

All multiple-choice questions must be answered on the Part A Response Page included in your test.

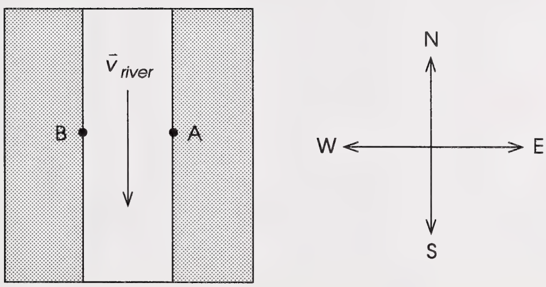
Read each question carefully and decide which of the choices BEST completes the statement or answers the question. Locate the question number on the Response Page and place your answer in the corresponding blank.

Consider all numbers used in the questions to be the result of a measurement.

1. A unit that could be used for momentum is

   A. $kg \bullet m/s^2$
   B. $kg \bullet cm/s$
   C. $kg \bullet m$
   D. $N \bullet m$

2. A river flows south as shown in the following diagram.



   A person wants to travel directly from point A to point B using a motorboat on the river. Which direction should the person point the boat to travel in a straight line across the river?

   A. northwest
   B. southwest
   C. northeast
   D. southeast

3. Which statement about potential energy is false?

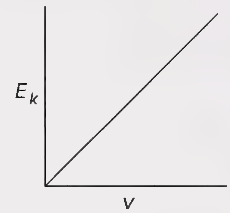
   A. Potential energy is always associated with a force.
   B. Potential energy is stored energy.
   C. Potential energy is able to do work.
   D. Potential energy is associated with moving things.

4. A unit equivalent to $\sqrt{\frac{\text{kg}}{\text{N/m}}}$ is

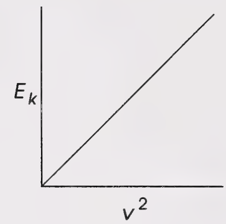
A. s
B. N
C. J
D. kg/s

5. Which graph for kinetic energy is correct?

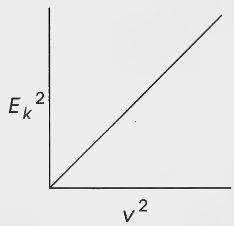
A.



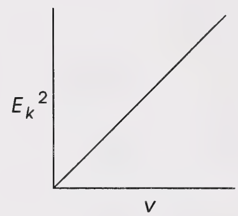
B.



C.



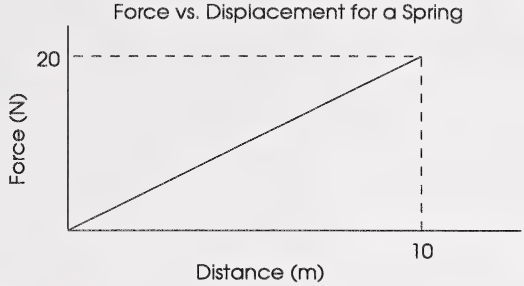
D.



6. Which of the following accurately describes the system of a rock falling from a mountain ledge?

A. The falling rock alone is an isolated system.
B. The rock and air around it form an isolated system.
C. The rock, air, and Earth form an isolated system.
D. There is no isolated system that contains the rock.

7. The following graph was produced from measurements taken from an object compressing a spring.



The work done by the object while compressing the spring is found by using

A. the slope of the line
B. the reciprocal of the line's slope
C. the area under the line
D. the *y*-intercept of the line

8. A body of mass *m* kg is shot vertically upwards at a speed of *v* m/s. An expression for the maximum height it can attain is

A. $h = \frac{mv}{g}$

B. $h = \frac{v^2}{2g}$

C. $h = \frac{2v^2}{g}$

D. $h = mg$

9. Which of the following statements explains that it is less damaging to fall onto a pile of straw than onto pavement?

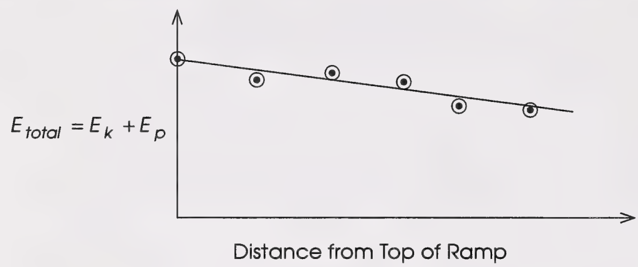
A. The change in momentum is greater for the landing on pavement.
B. The change in momentum is greater for the landing on the straw pile.
C. The time of impact is longer and the force is less for the landing on the straw.
D. The distance travelled while landing is greater for the landing on the straw.

10. Which of the following best describes a perfectly elastic collision?

A. Momentum and kinetic energy are both conserved.
B. Momentum and potential energy are both conserved.
C. Kinetic energy and potential energy are both conserved.
D. Potential energy and velocity are both conserved.

Use the following information to answer questions 11 and 12.

Students conducted an experiment in which potential energy and kinetic energy were both carefully measured as an object slid down a ramp. The students determined the kinetic energy and potential energy for six locations along the ramp. The following graph shows how the sum of the kinetic energy and potential energy changed as the object moved down the ramp.



11. The students who did the experiment were expecting the graph of E_{total} to be parallel to the x-axis. Which of the following energies that were not measured in the experiment best accounts for the slope of the graph?

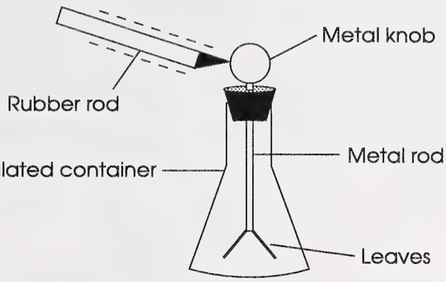
    A. thermal energy
    B. sound energy
    C. light energy
    D. chemical potential energy

12. What feature of the students' graph could be used to determine the average force of friction for the motion down the ramp?

    A. area under the line
    B. slope of the line
    C. x-intercept (extrapolated)
    D. y-intercept

Use the following information to answer questions 13 and 14.

An experiment was performed where a rubber rod was initially rubbed with fur and then the rubber rod was momentarily touched to a neutral electroscope.



The rubber rod was removed after touching the electroscope.

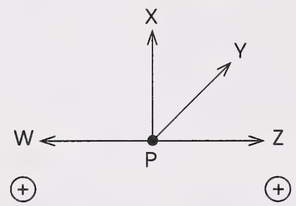
13. The best explanation of what occurred when the charged rubber rod was touched momentarily to the electroscope knob is

    A. Excess negative charges from the rod flow into the neutral electroscope.
    B. Excess positive charges from the rod flow into the neutral electroscope.
    C. Positive charges in the electroscope flow into the rod to neutralize the excess negative charges in the rod.
    D. Negative charges in the electroscope flow into the rod to neutralize the excess positive charges in the rod.

14. After the charged rubber rod is removed, the resulting charge on the rubber rod, the knob of the electroscope, and the leaves of the electroscope, successively, would be

    A. positive, positive, positive
    B. negative, neutral, neutral
    C. negative, positive, negative
    D. negative, negative, negative

15. Two equally charged spheres are shown.

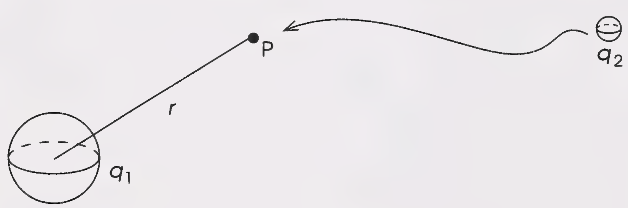


The direction of the electric field at point P would most likely be

A. W
B. X
C. Y
D. Z

Use the following information to answer question 16.

Charge q_1 sets up an electric field at point P as shown in the following diagram.



Charge q_2 is moved to point P.

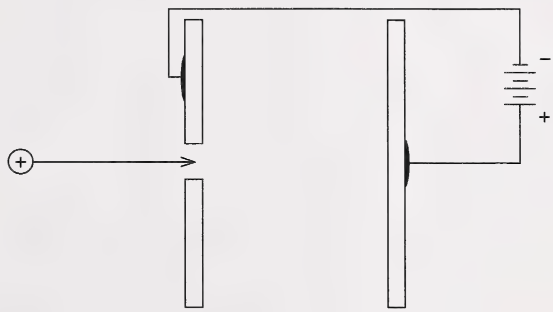
16. Which of the following techniques is a valid method of determining the electric field due to q_1 at point P?

A. Divide the electric force between the charges by q_2.
B. Multiply the electric force between the charges by q_1.
C. Divide the electric force between the charges by q_1.
D. Multiply the electric force between the charges by q_2.

17. A charged particle moves through a uniform electric field in the direction of the electric force acting on the particle. In these circumstances, the particle

A. loses potential energy and gains kinetic energy
B. gains potential energy and loses kinetic energy
C. loses both potential energy and kinetic energy
D. gains both potential energy and kinetic energy

Use the following information to answer question 18.



A positive particle enters a region of uniform electric field between two parallel plates. The particle's motion is influenced by electric and gravitational effects, but frictional effects are negligible.

18. Which of the following best describes the horizontal and vertical components of the particle's motion?

A. The horizontal motion is uniform and the vertical motion is accelerated.
B. The horizontal motion is accelerated and the vertical motion is uniform.
C. The horizontal motion is accelerated and the vertical motion is accelerated.
D. The horizontal motion is uniform and the vertical motion is uniform.

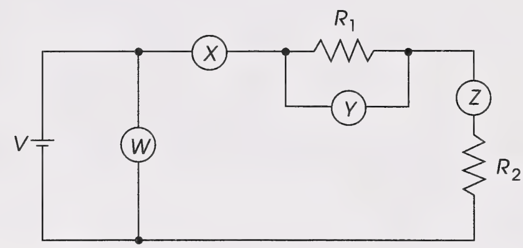
---

19. A camcorder battery has 1000 milliampere • hours as a specification written on the side. What quantity does this value represent?

A. power
B. current
C. voltage
D. charge

Use the following information to answer question 20.

A student constructed a circuit using two resistors and four meters labelled *W*, *X*, *Y*, and *Z*. The following schematic represents the circuit.



20. Which of the meters are connected correctly as ammeters and which ones are connected correctly as voltmeters?

 A. Only meter *Z* is set up correctly as an ammeter, while only meter *Y* is set up correctly as a voltmeter.
 B. Only meter *Y* is set up correctly as an ammeter, while only meter *Z* is set up correctly as a voltmeter.
 C. Meters *W* and *Y* are set up correctly as ammeters, while meters *X* and *Z* are set up correctly as voltmeters.
 D. Meters *X* and *Z* are set up correctly as ammeters, while meters *W* and *Y* are set up correctly as voltmeters.

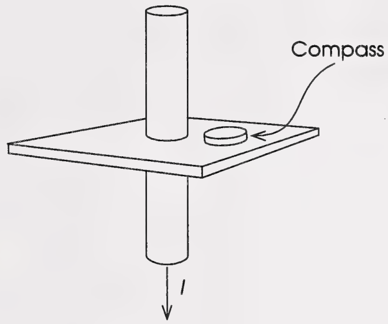
---

21. Why does the filament wire of a light bulb in a flashlight get hot enough to emit light, while the connecting wires of the flashlight stay cool?

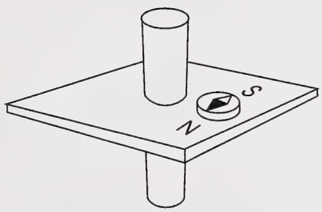
 A. The current through the filament wire is greater than the current through the connecting wires.
 B. The filament wire has a greater resistance than the connecting wire.
 C. The filament wire inside the light bulb is surrounded by a partial vacuum, while the connecting wires are not.
 D. The filament wire is shorter than the connecting wires.

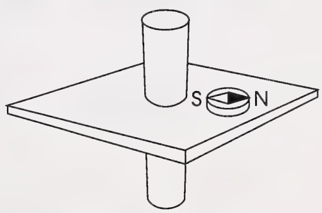
Use the following information to answer question 22.

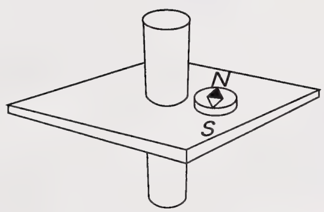
A compass is placed on a horizontal surface to the right of a wire carrying a vertical conventional current.

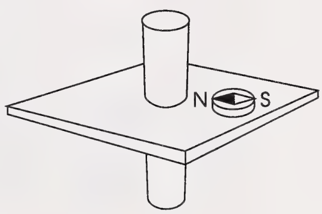


22. Which of the following diagrams best shows the proper orientation of the compass needle?

A.


B.


C.


D.


---

23. A charged particle enters a magnetic field and travels in a circular path. The product qBR has the same unit as

A. energy
B. current
C. momentum
D. power

Use the following information to answer question 24.

The equation for the magnetic field of a coil is given as follows: $B = 4\pi k' I \frac{N}{\ell}$.

B = magnetic field strength of a coil

k' = coil constant

I = current passing through coils

N = number of turns of wire

ℓ = length of coil

24. The SI units for the coil constant k' are

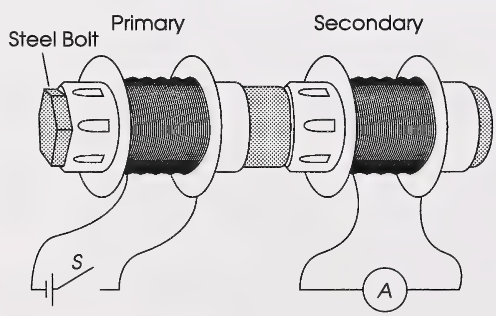
A. $\frac{\text{N}}{\text{A}^2}$

B. $\frac{\text{N}}{\text{A}^2\text{m}}$

C. N

D. $\frac{\text{T}}{\text{A}}$

Use the following information to answer question 25.



A student constructed the device shown to the left.

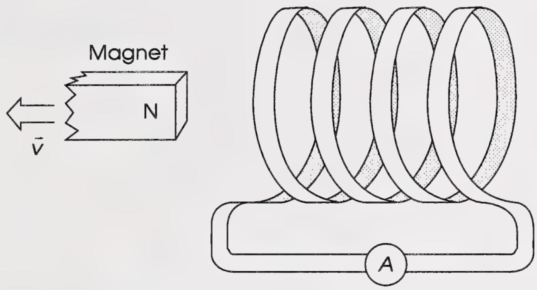
The primary coil is connected to a source of voltage with a switch.

The secondary coil is connected to an ammeter.

25. When the switch, *S*, is closed, the conventional current in the secondary solenoid

A. remains at zero
B. rises rapidly to a maximum and remains there
C. rises rapidly to a maximum and then reverses direction
D. rises rapidly to a maximum and then decreases to zero

Use the following diagram to answer question 26.



A magnet is being pulled to the left from a solenoid, as shown in the diagram.

26. Which of the following statements is false?

    A. The conventional current flow through the ammeter is from left to right.
    B. The coil is induced to have a south magnetic pole closest to the magnet.
    C. Magnetic field lines appear within the coil running from left to right.
    D. The magnetic field strength of the coil varies with the speed of the magnet.

---

27. An electromagnetic wave is determined to have a wavelength of 1.20×10^{-6} m. This radiation would best be employed in

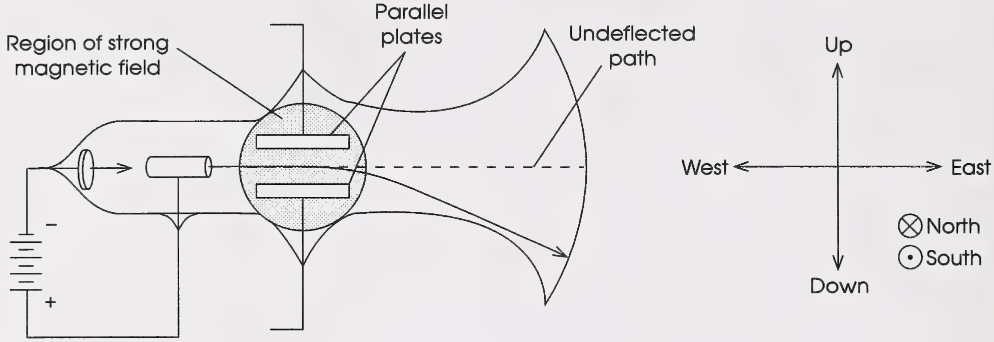
    A. a tanning parlour
    B. checking for broken bones
    C. radio broadcasting
    D. warming food

28. The source of all electromagnetic radiation is

    A. a transition to a lower energy level within an atom
    B. emission of electrons from a hot cathode
    C. an accelerating charge
    D. radioactive decay

Use the following diagram to answer questions 29 and 30.

During an experiment with cathode rays, the beam was initially directed due east. When the beam travelled through an intense magnetic field, it was observed to be deflected down, as shown in the following diagram.



The parallel plates were not charged when the beam was deflected as shown.

29. What was the direction of the magnetic field lines to produce the effect described in the diagram?

A. up
B. down
C. north
D. south

30. When the parallel plates are used to create an undeflected beam in the region of a strong magnetic field, which of the following best describes the conditions?

A. $mg = qvB_{\perp}$

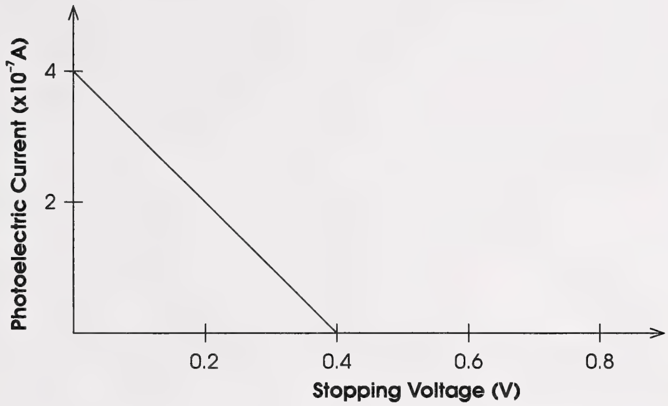
B. $mg = q\left|\vec{E}\right|$

C. $qvB = \dfrac{mv^2}{r}$

D. $qvB = q\vec{E}$

Use the following graph to answer question 31.

This graph came from data collected in a photoelectric experiment.



31. Which feature of the graph corresponds to the maximum kinetic energy of the photoelectrons?

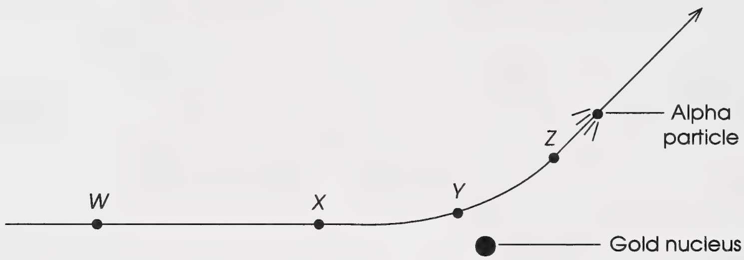
A. *x*-intercept
B. *y*-intercept
C. slope of the line
D. area under the line

32. A photosensitive metal is illuminated with light of wavelength 400 nm. No photoelectrons are emitted. Which of the following statements about this situation is true?

A. Brighter light of the same wavelength would produce photoelectrons.
B. The threshold wavelength for the metal must be less than 400 nm.
C. If the stopping voltage in the cell was increased, the metal would emit photoelectrons.
D. The frequency of the light used is too high for the photoelectric effect to start working.

Use the following information to answer questions 33 and 34.

The following diagram represents the path of an alpha particle being deflected by a gold nucleus. Points along the path have been labelled *W*, *X*, *Y*, and *Z*.



33. Which of the following equations best describes the repelling force between the alpha particle and the gold nucleus?

A. $F = \dfrac{mv^2}{r}$
B. $F = qvB_{\perp}$
C. $F = \dfrac{kqq}{r^2}$
D. $F = \dfrac{Gmm}{r^2}$

34. Potential energy can be stored by the system which includes the gold nucleus and the alpha particle. At which point along the path of the alpha particle is this potential energy at a maximum?

A. *W*
B. *X*
C. *Y*
D. *Z*

Use the following information to answer question 35.

The following statements describe types of nuclear reactions.

I. $A + B \rightharpoonup C$; the mass of C is greater than $A + B$.
II. $A + B \rightharpoonup C$; the mass of C is less than $A + B$.
III. $C \rightharpoonup A + B$; the mass of C is greater than $A + B$.
IV. $C \rightharpoonup A + B$; the mass of C is less than $A + B$.

35. Which of these statements best describe fusion and fission?

A. Fusion: statement I; Fission: statement IV
B. Fusion: statement I; Fission: statement III
C. Fusion: statement II; Fission: statement III
D. Fusion: statement II; Fission: statement IV

PART A: RESPONSE PAGE

______	1.	______	19.
______	2.	______	20.
______	3.	______	21.
______	4.	______	22.
______	5.	______	23.
______	6.	______	24.
______	7.	______	25.
______	8.	______	26.
______	9.	______	27.
______	10.	______	28.
______	11.	______	29.
______	12.	______	30.
______	13.	______	31.
______	14.	______	32.
______	15.	______	33.
______	16.	______	34.
______	17.	______	35.
______	18.		

Name of Student ______________________ Student I.D. # ______________

Name of School ______________________ Date ______________

Value

PART B: NUMERICAL RESPONSE

14

Answer each of the following questions using the space available on the Part B Response Page included in your test.

Consider all numbers used in the questions to be the result of a measurement.

Only the final answer is required on the Response Page.

1. The kinetic energy of a 35.0-g bullet travelling at 3.60×10^{2} km/h is $b \times 10^{w}$ J. The value of b is ______. (Round and record your answer to three digits.)

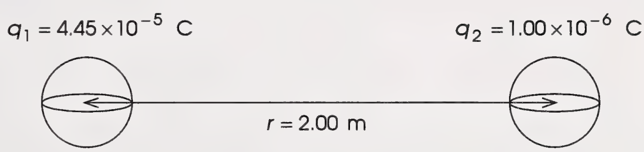
2. An elastic band is stretched 13 cm by an average force of 0.25 N. The maximum kinetic energy that it can transfer to a projectile is $B \times 10^{-W}$ J. The value for W is ______.

3. Two marbles, A and B with masses of 20 g and 34 g respectively, collide on a flat frictionless surface. The initial velocities are $\vec{v}_A = 15$ cm/s east and $\vec{v}_B = 12$ cm/s west. After collision, A ends up travelling west at 18 cm/s, while B travels east at ______ cm/s. (Round and record your answer to two digits.)

4. Air puck A with a mass of 0.550 kg is travelling at 67.4 cm/s when it collides with an identical stationary puck B. The pucks stick together. After collision, their combined speed will be ______ cm/s. (Round and record your answer to three digits.)

Use the following information to answer question 5.

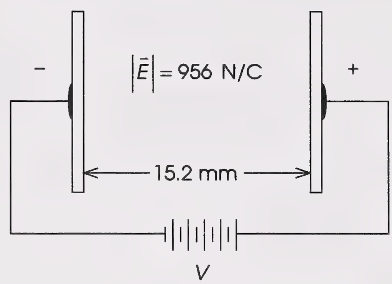
Two test charges, q_1 and q_2, are separated by a distance of 2.00 m.



5. The magnitude of the electric field created by q_1 at the location occupied by q_2 is $b \times 10^{w}$ N/C. The value of b is ______. (Round and record your answer to three digits.)

Use the following information to answer questions 6 and 7.

Two parallel plates create an electric field in the region between them.

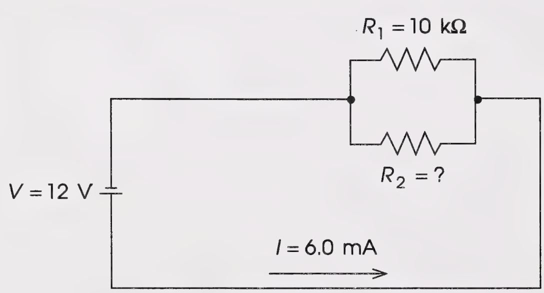


6. If an electron was placed in the region between the plates, its acceleration would be $b \times 10^{w}$ m/s^2. The value of b is ______. (Round and record your answer to three digits.)

7. The potential difference supplied to the parallel plates is $b \times 10^{w}$ V. The value of w is ______.

Use the following information to answer question 8.

The following schematic diagram represents a circuit constructed by a student in an investigation. The student used a multimeter to measure the values indicated.



8. The resistance of the resistor, R_2, is $b \times 10^{w}$ kΩ. The value of b is ______. (Round and record your answer to two digits.)

9. A total charge of 420 C passes through an 80.0-cm length of wire every 1.25 min. When the wire is placed at 90° to a magnetic field, it will experience a force of 5.36×10^{-3} N. The magnitude of the magnetic field is $b\times10^{-w}$ T. The value of w is equal to ______.

10. An electron travelling at 4.22×10^{5} m/s enters a magnetic field of 6.0×10^{-4} T and travels in a circular path having a radius of 4.0×10^{-3} m. The kinetic energy of the electron is $b\times10^{-w}$ J. The value for b is ______. (Round and record your answer to two significant digits.)

11. A 15.0-cm length of wire is forced to move with uniform motion through a magnetic field of 4.25×10^{-3} T. Since the wire is perpendicular to the magnetic field lines, a potential difference of 0.240 V is induced across the ends of the wire. The speed of the wire is $b\times10^{w}$ m/s. The value of b is ______. (Round and record your answer to three digits.)

Use the following information to answer questions 12 and 13.

A metal surface is incorporated into an apparatus designed to study the photoelectric effect. The work function of this metal is 2.05 eV.

12. The minimum frequency of light that will cause photoelectrons to be emitted from the metal surface is $b\times10^{w}$ Hz. The value of b is ______. (Round and record your answer to three digits.)

13. Photoelectrons are emitted with a maximum kinetic energy of 4.16 eV. The wavelength of the monochromatic light is $b\times10^{-w}$ m. The value of b is ______. (Round and record your answer to three digits.)

---

14. A sample of hydrogen atoms in the ground state are exposed to a source of electromagnetic radiation. It is observed that photons with an energy of 12.09 eV are absorbed by the sample. This corresponds to the hydrogen atoms in the sample being excited to energy level n. The value of n is ______.

PART B: RESPONSE PAGE

______	1.	______	8.
______	2.	______	9.
______	3.	______	10.
______	4.	______	11.
______	5.	______	12.
______	6.	______	13.
______	7.	______	14.

Name of Student ______________________	Student I.D. # ______________
Name of School ______________________	Date ______________

Value

PART C: WRITTEN RESPONSE

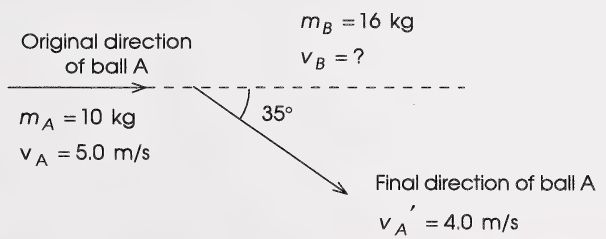
21 Answer each of the following questions using the space provided.

For full marks, your answers must show all pertinent explanations, calculations, and equations.

Your answers should be presented in a well-organized manner using sentences for a written response, and correct units and significant digits for a numerical response.

Consider all numbers used in the questions to be the result of a measurement.

5 1. A ball with a mass of 10 kg is rolling on a frictionless surface with a speed of 5.0 m/s. It collides with a stationary ball with a mass of 16 kg. After collision, the first ball deflects 35° to the right with a speed of 4.0 m/s, as shown in the following diagram.



Determine the magnitude and direction of the momentum of ball B after collision.

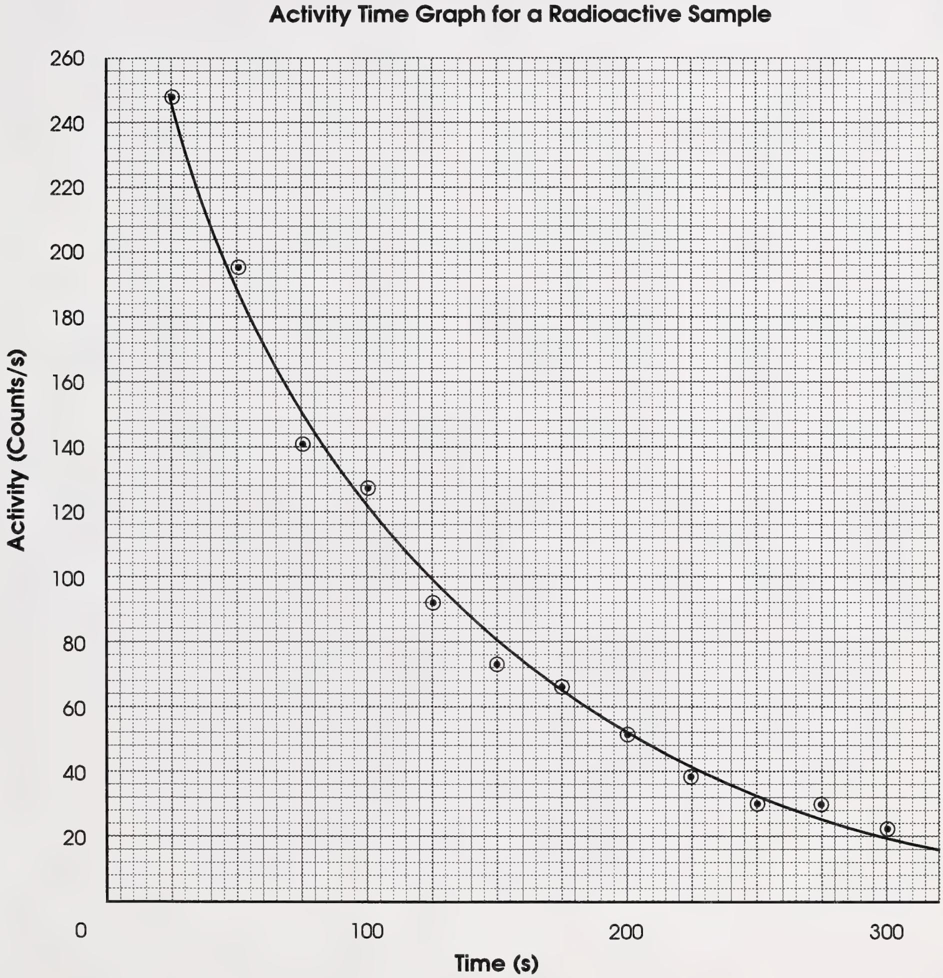
(There is more room for your answer on the next page.)

Name of Student		Student I.D. #	
Name of School		Date	

Name of Student		Student I.D. #	
Name of School		Date	

3

2. An experiment was done to carefully measure the radioactivity of a sample over a period of time. The results of this experiment are shown on the graph that follows.



Use the data presented on the graph to determine the best estimate of the half-life of this sample.

Name of Student ______	Student I.D. # ______
Name of School ______	Date ______

6

3. Two identical and equally charged spheres are carefully arranged in a Coulomb's-law-type experiment. The distance between the spheres is increased and the corresponding force between the spheres is measured. The data shown to the right is collected.

r (m)	F_e (N)
0.50	18
0.60	11
0.70	9
0.80	7
0.90	6
1.00	4

a. Manipulate the data to plot a straight-line graph with force on the vertical axis.

Name of Student ______________________ Student I.D. # ______________

Name of School ______________________ Date ______________

b. Calculate the slope of the graph.

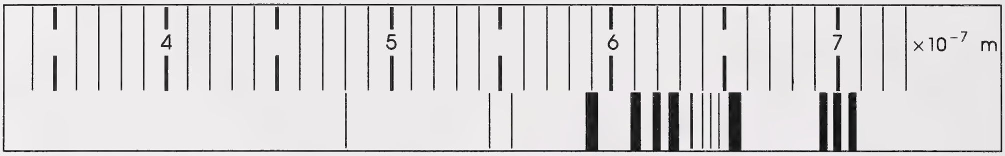
c. Use the slope of the graph to calculate a value for the charge on one of the spheres. (If you were unable to calculate a slope in part b, use $3.9\ \mathrm{N \bullet m^2}$ for the slope.)

Name of Student ______________________	Student I.D. # ______________
Name of School ______________________	Date ______________

7

4. Nicole notices a neon-type sign hanging in a shop window. A neon-type sign runs on the same principle as a gas discharge tube. The glass is usually bent into the shapes of letters which glow with the characteristic colour of the gas inside. Nicole is curious about the orange/red light from the sign, so she decides to return to the store with a spectroscope and notebook.

Using her spectroscope she records the following spectrum.



Next Nicole looks at the plate on the back of the power supply to the sign. She records the information exactly as it appears on the label.

Neon Sign Transformer: Model # 3842B

INPUT (PRIMARY COIL)	OUTPUT (SECONDARY COIL)
120 V	15000 V
3.90 A	30 mA
468 W	450 W

Made in Canada

a. Explain in general terms the energy transitions that occur inside the glass tube of the sign to produce the light.

Name of Student ______________________ Student I.D. # ______________

Name of School ______________________ Date ______________

b. Calculate the energy difference between any two of the energy levels in a neon atom.

c. Calculate the electric energy supplied to the gas in the tube by the secondary coil of the transformer each second.

d. Assume that the neon gas in the sign is only 25% efficient at converting electric energy to light energy. Estimate the total number of photons emitted by this sign in one second.

Name of Student ____________________	Student I.D. # ____________________
Name of School ____________________	Date ____________________

TEACHER QUESTIONNAIRE FOR PHYSICS 30

This is a course designed in a new distance-learning format, so we are interested in your responses. Your constructive comments will be greatly appreciated so that a future revision may incorporate any necessary improvements.

Teacher's Name ______________________ Area of Expertise ______________________

School Name ______________________ Date ______________________

Design

1. The modules follow a definite systematic design. Did you find it easy to follow?

   ❑ Yes ❑ No If no, explain.

   ____

   ____

2. Did your observations reveal that the students found the design easy to follow?

   ❑ Yes ❑ No If no, explain.

   ____

   ____

3. Did you find the Learning Facilitator's Manual helpful?

   ❑ Yes ❑ No If no, explain.

   ____

   ____

4. Part of the design involves stating the objectives in student terms. Do you feel this helped the students understand what they were going to learn?

   ❑ Yes ❑ No If no, explain.

   ____

   ____

5. The Learning Facilitator's Manual contains Assignment answers and a sample test. Did you find these helpful?

❑ Yes ❑ No If no, explain.

---

6. Did the Follow-up Activities prove to be helpful?

❑ Yes ❑ No If no, explain.

---

7. Were students motivated to try these Follow-up Activities?

❑ Yes ❑ No If no, give details.

---

8. Suggestions for computer and video activities are included in the course. Were your students able to use these activities?

❑ Yes ❑ No Comment on the lines below.

---

9. Were the assignments appropriate?

❑ Yes ❑ No If no, give details.

---

10. Did you fax assignments? ❑ Yes ❑ No

11. If you did fax, did you get satisfactory results from using this procedure?

❑ Yes ❑ No If no, give details.

Instruction

1. Did you find the instruction clear?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

2. Did your observations reveal that the students found the instruction interesting?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

3. Did you find the instruction adequate?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

4. Was the reading level appropriate?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

5. Was the work load adequate?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

6. Was the content accurate and current?

   ❑ Yes ❑ No If no, give details.

   ____

   ____

7. Did the content flow consistently and logically?

❑ Yes ❑ No If no, give details.

8. Was the transition between booklets smooth?

❑ Yes ❑ No If no, give details.

9. Was the transition between print and media smooth?

❑ Yes ❑ No If no, give details.

Additional Comments

Thanks for taking the time to complete this survey. Your feedback is important to us.

Fax Number: 674-6686

Instructional Design and Development Unit
Alberta Distance Learning Centre
Box 4000
Barrhead, Alberta
T0G 2P0

Note: Please ensure that each of your students has completed and forwarded a copy of the Course Survey.

Masters for Pull-out Pages

You have permission from the publisher to photocopy these pages for your students.

These pages are used by students to complete some of the investigations in Physics 30. Keep these pages for future use. Note that the pages showing air-table data must be reproduced exactly as shown (with no enlarging or reduction) to ensure that your student's results match the key in the corresponding module Appendix.

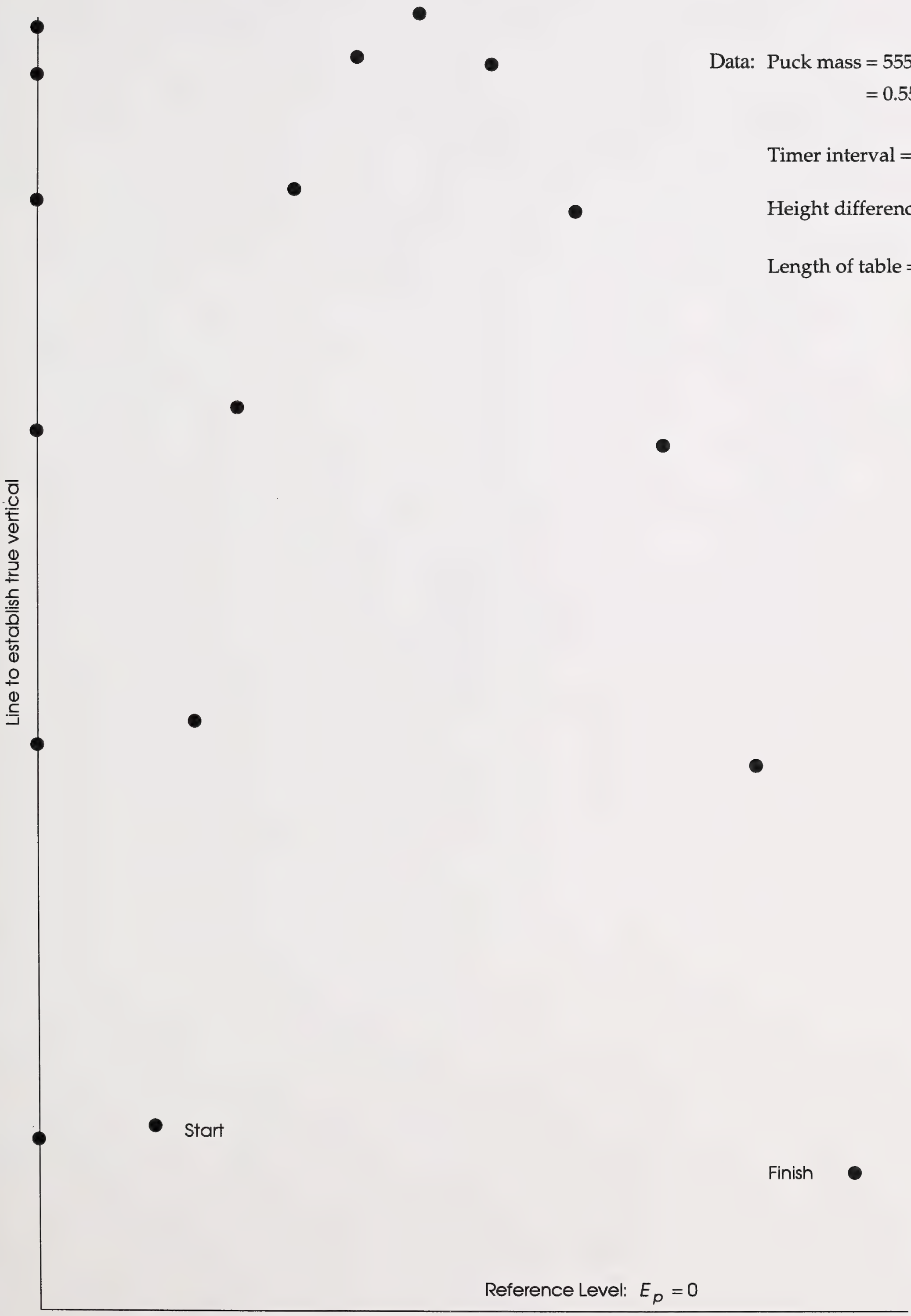
Module 1 Section 2: Activity 2 Investigation: Conservation of Energy on an Air Table

Data: Puck mass = 555 g
= 0.555 kg

Timer interval = 0.100 s

Height difference = 10.2 cm

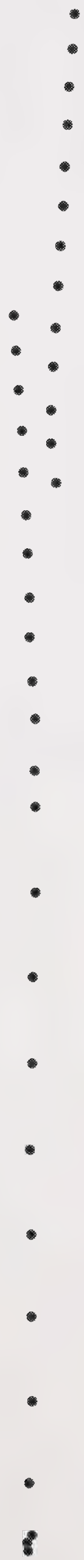
Length of table = 65.0 cm



Module 2 Section 2: Activity 2 Investigation: Conservation of Momentum in One Dimension

This is the sample data for Part B of this investigation.

End



Spark timer interval = 20 ms

Beginning

Module 2 Section 2: Activity 4 Investigation: A Two-Dimensional Collision

This is the sample data for Part B of this investigation.

Module 2 Section 2: Activity 5 Applications in Two Dimensions

This is the sample data for question 4 of this activity.

Source:

Source:

Source:

Source:

Source:

Source:

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Source:

Masters for Physics 30 Data Sheets

You have permission from the publisher to photocopy these pages for your students.

These pages are used by students throughout the Physics 30 course. Each student should be given a copy to use while working on assignments, investigations, and other classroom activities.

You should run off a class set of these sheets for exclusive use on quizzes, exams, and the final test. This set of the data sheets should be kept clean of any marks or notes that students may happen to make so that your students can practise performing under Physics 30 Diploma Exam conditions.

PHYSICS 30
DATA SHEETS

CONSTANTS

GRAVITY, ELECTRICITY, AND MAGNETISM

Acceleration Due to Gravity or Gravitational Field Near Earth	g or $a_g = 9.81\ \mathrm{m/s^2}$ or $9.81\ \mathrm{N/kg}$
Gravitational Constant	$G = 6.67 \times 10^{-11}\ \mathrm{N \bullet m^2/kg^2}$
Mass of Earth	$M_e = 5.98 \times 10^{24}\ \mathrm{kg}$
Radius of Earth	$R_e = 6.37 \times 10^{6}\ \mathrm{m}$
Coulomb's Law Constant	$k = 8.99 \times 10^{9}\ \mathrm{N \bullet m^2/C^2}$
Electron Volt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$
Elementary Charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
Index of Refraction of Air	$n = 1.00$
Speed of Light in Vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m/s}$

ATOMIC PHYSICS

Energy of an Electron in the 1st Bohr Orbit of Hydrogen	$E_1 = -2.18 \times 10^{-18}\ \mathrm{J}$ or $-13.6\ \mathrm{eV}$
Planck's Constant	$h = 6.63 \times 10^{-34}\ \mathrm{J \bullet s}$
Radius of 1st Bohr Orbit of Hydrogen	$r_1 = 5.29 \times 10^{-11}\ \mathrm{m}$
Rydberg's Constant for Hydrogen	$R_H = 1.10 \times 10^{7}\ \mathrm{/m}$

PARTICLES

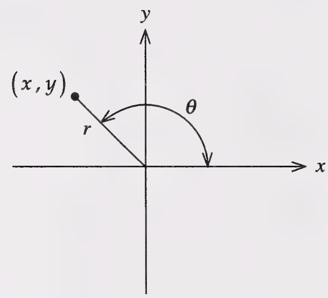
	Rest Mass	Charge
Alpha Particle	$m_\alpha = 6.65 \times 10^{-27}$ kg	α^{2+}
Electron	$m_e = 9.11 \times 10^{-31}$ kg	e^-
Neutron	$m_n = 1.67 \times 10^{-27}$ kg	n^0
Proton	$m_p = 1.67 \times 10^{-27}$ kg	p^+

Trigonometry and Vectors

$$\sin\theta = \frac{opposite}{hypotenuse} \text{ or } \sin\theta = \frac{y}{r}$$

$$\cos\theta = \frac{adjacent}{hypotenuse} \text{ or } \cos\theta = \frac{x}{r}$$

$$\tan\theta = \frac{opposite}{adjacent} \text{ or } \tan\theta = \frac{y}{x}$$



For any Vector $\vec{R}$

$$R = \sqrt{R_x{}^2 + R_y{}^2}$$

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

$$\tan\theta = \frac{R_y}{R_x}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

VALUES OF TRIGONOMETRIC FUNCTIONS

Angle	Sin	Cos	Tan	Angle	Sin	Cos	Tan
1°	0.0175	0.9998	0.0175	46°	0.7193	0.6947	1.0355
2°	0.0349	0.9994	0.0349	47°	0.7314	0.6820	1.0724
3°	0.0523	0.9986	0.0524	48°	0.7431	0.6691	1.1106
4°	0.0698	0.9976	0.0699	49°	0.7547	0.6561	1.1504
5°	0.0872	0.9962	0.0875	50°	0.7660	0.6428	1.1918
6°	0.1045	0.9945	0.1051	51°	0.7771	0.6293	1.2349
7°	0.1219	0.9925	0.1228	52°	0.7880	0.6157	1.2799
8°	0.1392	0.9903	0.1405	53°	0.7986	0.6018	1.3270
9°	0.1564	0.9877	0.1584	54°	0.8090	0.5878	1.3764
10°	0.1736	0.9848	0.1763	55°	0.8192	0.5736	1.4281
11°	0.1908	0.9816	0.1944	56°	0.8290	0.5592	1.4826
12°	0.2079	0.9781	0.2126	57°	0.8387	0.5446	1.5399
13°	0.2250	0.9744	0.2309	58°	0.8480	0.5299	1.6003
14°	0.2419	0.9703	0.2493	59°	0.8572	0.5150	1.6643
15°	0.2588	0.9659	0.2679	60°	0.8660	0.5000	1.7321
16°	0.2756	0.9613	0.2867	61°	0.8746	0.4848	1.8040
17°	0.2924	0.9563	0.3057	62°	0.8829	0.4695	1.8807
18°	0.3090	0.9511	0.3249	63°	0.8910	0.4540	1.9626
19°	0.3256	0.9455	0.3443	64°	0.8988	0.4384	2.0503
20°	0.3420	0.9397	0.3640	65°	0.9063	0.4226	2.1445
21°	0.3584	0.9336	0.3839	66°	0.9135	0.4067	2.2460
22°	0.3746	0.9272	0.4040	67°	0.9205	0.3907	2.3559
23°	0.3907	0.9205	0.4245	68°	0.9272	0.3746	2.4751
24°	0.4067	0.9135	0.4452	69°	0.9336	0.3584	2.6051
25°	0.4226	0.9063	0.4663	70°	0.9397	0.3420	2.7475
26°	0.4384	0.8988	0.4877	71°	0.9455	0.3256	2.9042
27°	0.4540	0.8910	0.5095	72°	0.9511	0.3090	3.0777
28°	0.4695	0.8829	0.5317	73°	0.9563	0.2924	3.2709
29°	0.4848	0.8746	0.5543	74°	0.9613	0.2756	3.4874
30°	0.5000	0.8660	0.5774	75°	0.9659	0.2588	3.7321
31°	0.5150	0.8572	0.6009	76°	0.9703	0.2419	4.0108
32°	0.5299	0.8480	0.6249	77°	0.9744	0.2250	4.3315
33°	0.5446	0.8387	0.6494	78°	0.9781	0.2079	4.7046
34°	0.5592	0.8290	0.6745	79°	0.9816	0.1908	5.1446
35°	0.5736	0.8192	0.7002	80°	0.9848	0.1736	5.6713
36°	0.5878	0.8090	0.7265	81°	0.9877	0.1564	6.3138
37°	0.6018	0.7986	0.7536	82°	0.9903	0.1392	7.1154
38°	0.6157	0.7880	0.7813	83°	0.9925	0.1219	8.1443
39°	0.6293	0.7771	0.8098	84°	0.9945	0.1045	9.5144
40°	0.6428	0.7660	0.8391	85°	0.9962	0.0872	11.4301
41°	0.6561	0.7547	0.8693	86°	0.9976	0.0698	14.3007
42°	0.6691	0.7431	0.9004	87°	0.9986	0.0523	19.0811
43°	0.6820	0.7314	0.9325	88°	0.9994	0.0349	28.6363
44°	0.6947	0.7193	0.9657	89°	0.9998	0.0175	57.2900
45°	0.7071	0.7071	1.0000	90°	1.0000	0.0000	Undefined

EQUATIONS

Kinematics

$$\vec{v}_{ave} = \frac{\vec{d}}{t}$$

$$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$v_f^2 = v_i^2 + 2ad$$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

Dynamics

$$\vec{F} = m\vec{a}$$

$$F_g = \frac{Gm_1 m_2}{r^2}$$

$$\vec{F}t = m\Delta\vec{v}$$

$$g = \frac{Gm_1}{r^2}$$

$$\vec{F}_g = m\vec{g}$$

$$F_c = \frac{mv^2}{r}$$

$$F_f = \mu F_N$$

$$F_c = \frac{4\pi^2 mr}{T^2}$$

$$\vec{F}_s = -k\vec{x}$$

Momentum and Energy

$$\vec{p} = m\vec{v}$$

$$E_k = \frac{1}{2}mv^2$$

$$W = Fd$$

$$E_p = mgh$$

$$W = Fd\cos\theta$$

$$E_p = \frac{1}{2}kx^2$$

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

Waves and Light

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\lambda = \frac{xd}{nl}$$

$$T = \frac{1}{f}$$

$$\lambda = \frac{d\sin\theta}{n}$$

$$v = f\lambda$$

$$m = \frac{h_i}{h_0} = \frac{-d_i}{d_0}$$

$$\frac{\lambda_1}{2} = l; \ \frac{\lambda_1}{4} = l$$

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$$

EQUATIONS

Electricity and Magnetism

$$F_e = \frac{kq_1q_2}{r^2}$$

$$|\vec{E}| = \frac{kq_1}{r^2}$$

$$\vec{E} = \frac{\vec{F}_e}{q}$$

$$|\vec{E}| = \frac{V}{d}$$

$$V = \frac{\Delta E}{q}$$

$$R = R_1 + R_2 + R_3$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$V = IR$$

$$P = IV$$

$$I = \frac{q}{t}$$

$$F_m = IlB_\perp$$

$$F_m = qvB_\perp$$

$$V = B_\perp lv$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$V_{eff} = 0.707\ V_{max}$$

$$I_{eff} = 0.707\ I_{max}$$

Atomic Physics

$$hf = E_{k_{max}} + W$$

$$W = hf_0$$

$$E_{k_{max}} = qV_{stop}$$

$$E = hf = \frac{hc}{\lambda}$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

$$E_n = \frac{1}{n^2}E_1$$

$$r_n = n^2 r_1$$

Relativity and Quantum Physics

$$E = mc^2$$

$$p = \frac{h}{\lambda}$$

$$p = \frac{hf}{c};\ E = pc$$

Periodic Chart of the Elements

Key

ATOMIC NUMBER → 1 H ← SYMBOL OF THE ELEMENT

2.1 ← ELECTRONEGATIVITY

NAME OF THE ELEMENT → hydrogen

ATOMIC MASS → 1.01

BASED ON $^{12}_{6}C$

( ) INDICATES MASS OF THE MOST STABLE ISOTOPE

Note: The Legend at the right denotes the physical state of the elements at 101 kPa and 298 K (25°C)

Legend

SOLID

LIQUID

GAS

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA or 0
1 H 2.1 hydrogen 1.01																	2 He – helium 4.00
3 Li 1.0 lithium 6.94	4 Be 1.5 beryllium 9.01											5 B 2.0 boron 10.81	6 C 2.5 carbon 12.01	7 N 3.0 nitrogen 14.01	8 O 3.5 oxygen 16.00	9 F 4.0 fluorine 19.00	10 Ne – neon 20.17
11 Na 0.9 sodium 22.99	12 Mg 1.2 magnesium 24.31											13 Al 1.5 aluminum 26.98	14 Si 1.8 silicon 28.09	15 P 2.1 phosphorus 30.97	16 S 2.5 sulphur 32.06	17 Cl 3.0 chlorine 35.45	18 Ar – argon 39.95
19 K 0.8 potassium 39.10	20 Ca 1.0 calcium 40.08	21 Sc 1.3 scandium 44.96	22 Ti 1.5 titanium 47.90	23 V 1.6 vanadium 50.94	24 Cr 1.6 chromium 52.00	25 Mn 1.5 manganese 54.94	26 Fe 1.8 iron 55.85	27 Co 1.8 cobalt 58.93	28 Ni 1.8 nickel 58.71	29 Cu 1.9 copper 63.55	30 Zn 1.6 zinc 65.38	31 Ga 1.6 gallium 69.74	32 Ge 1.8 germanium 72.59	33 As 2.0 arsenic 74.92	34 Se 2.4 selenium 78.96	35 Br 2.8 bromine 79.90	36 Kr – krypton 83.80
37 Rb 0.8 rubidium 85.47	38 Sr 1.0 strontium 87.62	39 Y 1.3 yttrium 88.91	40 Zr 1.4 zirconium 91.22	41 Nb 1.6 niobium 92.91	42 Mo 1.8 molybdenum 95.94	43 Tc 1.9 technetium 98.91	44 Ru 2.2 ruthenium 101.07	45 Rh 2.2 rhodium 102.91	46 Pd 2.2 palladium 106.40	47 Ag 1.9 silver 107.87	48 Cd 1.7 cadmium 112.41	49 In 1.7 indium 114.82	50 Sn 1.8 tin 118.69	51 Sb 1.9 antimony 121.75	52 Te 2.1 tellurium 127.60	53 I 2.5 iodine 126.90	54 Xe – xenon 131.30
55 Cs 0.7 cesium 132.91	56 Ba 0.9 barium 137.33	57-71	72 Hf 1.3 hafnium 178.49	73 Ta 1.5 tantalum 180.95	74 W 1.7 tungsten 183.85	75 Re 1.9 rhenium 186.21	76 Os 2.2 osmium 190.20	77 Ir 2.2 iridium 192.22	78 Pt 2.2 platinum 195.09	79 Au 2.4 gold 196.97	80 Hg 1.9 mercury 200.59	81 Tl 1.8 thallium 204.37	82 Pb 1.8 lead 207.19	83 Bi 1.9 bismuth 208.98	84 Po 2.0 polonium (209)	85 At 2.2 astatine (210)	86 Rn – radon (222)
87 Fr 0.7 francium (223)	88 Ra 0.9 radium 226.03	89-103	104 Rf – rutherfordium (206)	105 Ha – hahnium (260)	106 – (263)	107 –											

57 La 1.1 lanthanum 138.91	58 Ce 1.1 cerium 140.12	59 Pr 1.1 praseodynium 140.91	60 Nd 1.2 neodymium 144.24	61 Pm – promethium (145)	62 Sm 1.2 samarium 150.35	63 Eu – europium 151.96	64 Gd 1.1 gadolinium 157.25	65 Tb 1.2 terbium 158.93	66 Dy – dysprosium 162.50	67 Ho 1.2 holmium 164.93	68 Er 1.2 erbium 167.26	69 Tm 1.2 thulium 168.93	70 Yb 1.1 ytterbium 173.04	71 Lu 1.2 iutetium 174.97
89 Ac 1.1 actinium (227)	90 Th 1.3 thorium 232.04	91 Pa 1.5 protactinium 231.04	92 U 1.7 uranium 238.03	93 Np 1.3 neptunium 237.05	94 Pu 1.3 plutonium (244)	95 Am 1.3 americium (243)	96 Cm – curium (247)	97 Bk – berkelium (247)	98 Cf – californium (251)	99 Es – einsteinium (254)	100 Fm – fermium (257)	101 Md – mendelevium (258)	102 No – nobelium (259)	103 Lr – lawrencium (260)

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